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User's Manual for SNL-SAND-II Code

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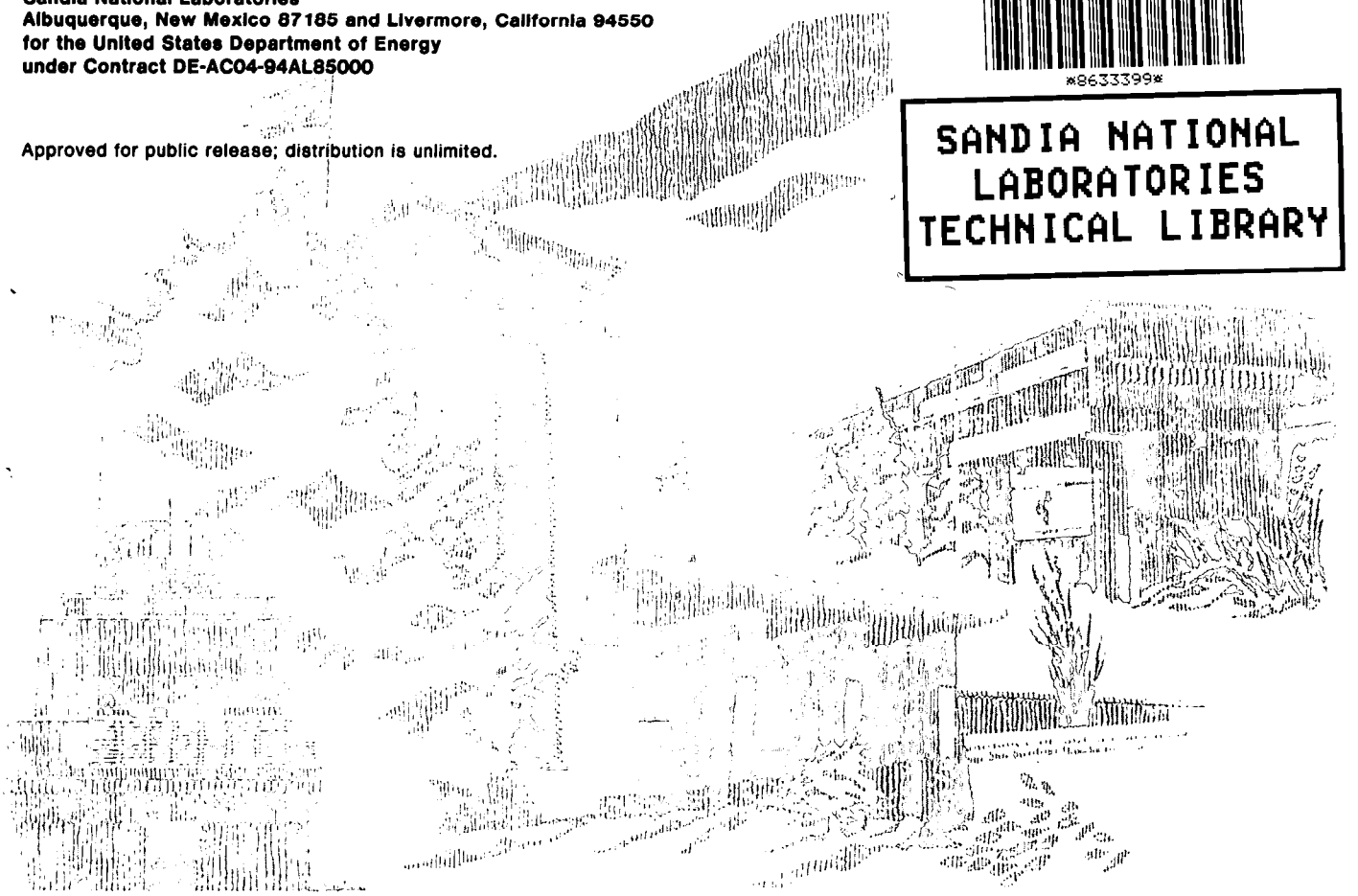

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Abstract

Sandia National Laboratories, in the process of characterizing the neutron environments at its reactor facilities, has developed an enhanced version of W. McElroy's original SAND-II code. The enhanced input, output, and plotting interfaces make the code much easier to use. The basic physics and operation of the code remain unchanged. Important code enhancements include the interfaces to the latest ENDF/B-VI and IRDF-90 dosimetry-quality cross sections and the ability to use silicon displacement-sensitive devices as dosimetry sensors.

Forward

This document was compiled in response to frequent requests to make the SNL version of the SAND-II code available to other organizations. Many of the requesting agencies are ones for whom we have provided technical assistance, either through a Work-for-Others program or through a technology transfer initiative. Sandia National Laboratories is glad to participate in joint programs that advance the state-of-the-art in the characterization of reactor neutron/photon environments and in the maintenance of quality reactor dosimetry.

The SNL-SAND-II code and this user's manual are the result of collaborations with other dosimetry laboratories. Please continue to let us know how we can be of assistance in maintaining high standards for reactor dosimetry.

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Executive Summary

This report documents the changes in the SNL-SAND-II input stream and describes the output interfaces provided with the SNL-SAND-II code. The expanded input formats and the enhanced output summaries simplify the characterization of neutron spectra. The SNL-SAND-II code does not represent any advancement in the mathematics of the original SAND-II algorithm. It does, however, provide an easy interface to the latest dosimetry-quality cross sections. This code also automates the process of using silicon displacement-sensitive devices as dosimetry sensors.

This manual, taken together with the original SAND-II documentation, should allow an analyst to use the SNL-SAND-II code to characterize a reactor neutron spectrum when a satisfactory trial function is known. If a good trial function is not known, other techniques such as those given in References 8 and 9 must be used to ensure that the spectrum is unfolded properly.

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User's Manual for SNL-SAND-II Code

1. Purpose

The SNL-SAND-II code is a Sandia National Laboratories' (SNL) version of W. McElroy's SAND-II code [1]. The baseline version of SAND-II, upon which modifications were made, was obtained as item CCC-112 from the Radiation Shielding Information Center (RSIC). SAND-II is an iterative spectrum unfolding code. The basic physics and operation of the code remain unchanged. The advantages of the SNL version are that it provides

- a better input format
- a much enhanced output report
- a UNIX-based plot interface built around the publicly available ACE/gr package [2]
- treatment of silicon devices as displacement sensors for dosimetry applications
- an interface to the SNLRML [3] compendium of dosimetry cross sections.

This memorandum describes the major changes made to the SAND-II code and provides instructions for installation on a UNIX computer. This report was prepared to provide a minimal set of documentation to accompany the distribution of the SNL-SAND-II code. This manual, used alone, is not sufficient to run the SNL-SAND-II code. It must be used in conjunction with the original SAND-II documentation [1]. It is recommended that a new user gain some experience using the original SAND-II code (as distributed by RSIC and referenced as code package CCC-112) before trying to use the SNL-SAND-II code.

This manual does not describe all of the changes made to the SAND-II code. Some features are not described here because they are not fully implemented or because they did not prove useful in spectra determination. This export version of the SNL-SAND-II code is identical to the version in current usage at the SNL Radiation Metrology Laboratory (RML). These undocumented features are left in the distributed code since existing funding does not permit the development and maintenance of an "export" version of SNL-SAND-II. The FORTRAN coding in SNL-SAND-II is unnecessarily complicated in some places due to the fact that the source has been modified in a series of "ports" to various computer platforms. The code could be considerably improved if modern software development principles were used to reorganize the source code logic flow. In the absence of funding to rewrite the code, the current version is being released to the dosimetry community.

2. Installation

The SNL-SAND-II code is being submitted to RSIC for distribution in accordance with the DOE code distribution policy defined in DOE order 1360.4B paragraph 8 [4]. The baseline version of the distributed code is for a Sun Sparc-2 system in a tar-format file. To install the code from a 1/4" tape on a Sparc-2 system into a user directory (the directory will be set to "/usr/codes/sandia/snlsand" in this example), a user should type the following commands:

```
cd /usr/codes/sandia/snlsand
tar -xvf /dev/rst0
```

If the code is distributed on a media other than a 1/4" tape at the default Sun SCSI address, the device name (/dev/rst0) in the installation should be changed to the appropriate unit. If a 3 1/4" floppy disk is used on a Sparc-2, the proper device name is /dev/fd0. If a different installation location is desired, the user should change the "/usr/codes/sandia/snlsand" directory location in the above commands to the desired directory. When these commands have been executed, several files will have been extracted from the tape. A list of the files restored during the installation, often referred to as a MANIFEST, is attached as Appendix D to this memorandum. One of the files created is called "README". The README file provides additional instructions for using the UNIX "make" utility to recompile the four codes within the SAND-II code family (CSTAPE, SLACTS, SLTAPE, and SAND-II) and to recreate the SNLRML cross section compendium in binary form, as required for SAND-II execution. A copy of the README file is also attached to this memorandum as Appendix C. The README file gives instructions for changing the ${dirstub} designation for the installation directory in all scripts.

The recompilation of the FORTRAN source code and reconstruction of the dosimetry library are described in the README document. After code installation, the test cases should be run to validate proper installation. The following commands should be executed to run the sample problems and to create "difference" files with the sample outputs.

```
cd /usr/codes/sandia/snlsand/input
testall
vi diffout
```

The last step uses the UNIX "vi" editor to examine the difference files between the outputs on the user platform and the sample outputs supplied with the code distribution. Other text editors may be used in place of "vi" to examine the "difference" files. If the "testall" program reports no differences in the test runs from the enclosed sample outputs, then this examination can be skipped. Small changes, reflecting numerical roundoff differences, might be seen on different platforms.

3. Machine Dependencies

The current version of the code is intended for a Sun Sparc-2. This code should be easily ported to any UNIX-based system. The code execution C-shell scripts should operate on any UNIX platform, but the makefile scripts will require some modification of the FORTRAN compiler invocation name and execution option flags. The FORTRAN source code does make use of some machine-dependent commands to read script-set UNIX environmental variables. These commands can be easily converted to the form required on other UNIX systems or, if equivalent FORTRAN system utilities do not exist on a given platform, the variable names can be hardwired into the FORTRAN source.

The current source code expects modules to exist at specific locations. The user is given some very flexible control over the location of these files through the "setenv" variables defined in the UNIX scripts. The location of files should not be changed until the user understands the current structure and feels comfortable with modifying both the FORTRAN source and the CSH (C-shell) scripts.

4. Use of Dosimetry Cross Section Libraries

The SNL-SAND-II code is distributed with the Sandia National Laboratories Radiation Metrology Library (SNLRML). This library has been submitted to RSIC as an individual data package. It is included in this code distribution to minimize SAND-II installation problems. The authors believe that the SNLRML represents the latest and most accurate set of dosimetry cross sections for use in unfolding fission spectra. References 5 and 6 document some of the testing and peer-review used in the development of this dosimetry library. Reference 3 gives details on the format of the ASCII cross section required by the SNL-SAND-II code. If a different library, but one having the same format, is used, it should be located in the /usr/codes/sandia/snlsand/cstape/input directory and the library reconstruction script /usr/codes/sandia/snlsand/make_library should be edited to replace the argument "SNLRML" with the name of the new library.

5. Quality Assurance Level

This code has been assigned an SNL quality level III designation*. In accordance with the Sandia Research Reactor and Experimental Programs (RREP) Quality Assurance Program Plan this designation implies a quality program of minimum scope. Failure of this code operations would:

**Sandia Research Reactor and Experimental Programs Quality Assurance Program Plan*, compiled by H. M. DeLap, Sandia National Laboratories Internal memorandum RS6450/ 89/00001.

Have no effect on health and safety.
Not affect design objectives.
Result in minor operational delays or unscheduled shutdowns for short periods of time.
Result in failure to achieve minor research and development goals within cost and schedule restraints.

If a user's quality requirements exceed this description, the user is responsible for implementing any necessary quality assurance testing, verification, and validation of the code operation.

6. Changes in SAND-II Input

The following sections describe the records in the SNL-SAND-II input stream that have been changed from that specified in the original documentation.

6.1 Title Record

The first record in the SNL-SAND-II input stream is now a title card. It is read with an 80A1 format and is echoed to the output file and as a run identifier in the plot files.

6.2 Control Integer Record

The second record in the SNL-SAND-II input stream is a set of 40 control integers that fill the ICON array. These control flags are read with a 40I2 format. These control flags activate various options, some of which are still under development. The recommended default options for these control flags is

```
0 0 4 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
```

The control flags are described in the following paragraphs. Some of these options are not recommended for use by the general user. While these option flags would normally be stripped from any general production version of this code, this code is regarded as a working version and is still evolving. Thus the options are left in place but the user is strongly discouraged from using them unless he has a through understanding of the logic flow of the code.

ICON(1) Mode of operation

- = 0 Normal SNL-SAND-II operation. This is the only option recommended for the general user.
- = 1 Special sensitivity analysis designed for analysis of Nuclear Accident Detectors. This option is not recommended at this time due to the lack of adequate documentation and insufficient testing.
- = 2 Loop over all built-in spectra as trial functions.
- = 3 Attempt at automating the J. G. Kelly technique [7, 8]for outer iterations with some intelligent built-in smoothing algorithms. This option uses additional input from ICON(9).

This option has not proven to be of great value. The logic to implement the outer iteration methodology, described in Reference 8, is not easily coded in FORTRAN.

ICON(2) Spectrum plot label control

= 0 Label energy sensitivity regions and resonance peaks for reactions in the plot of the differential neutron number spectrum. In order to avoid cluttering the plot, not all reactions are flagged within the code for this labeling. The reactions chosen for labeling were selected for their importance in achieving good energy coverage within the set of sensors used in typical SNL spectrum determinations.

≠ 0 Do not label sensitivity regions or resonance peaks.

ICON(3) Control of the amount of printout in the output file. The larger the number, the more printout that is inhibited.

> 3 Inhibit printing of the differential neutron number spectrum. On modern interactive workstations the neutron spectrum is usually interfaced electronically with auxiliary plotting codes. This option is recommended since visual inspection of a plot of a SAND-II generated spectrum is much more meaningful than a printed tabulation.

ICON(4) Cross section and response function plot option

= 0 Do not produce cross section and response function plots.

≠ 0 Produce cross section and response function plots.

ICON(5) Selection of reference library for spectra

= 0 Normal spectra reference file from SLTAPE output.

= 1 Special Nuclear Accident Detector spectra library. This option is not supported in the distributed version of the code and should not be invoked.

ICON(6) Option to inhibit the logic controlling sensor discard when convergence can not be obtained.

= 0 Normal SAND-II sensor discard policy is used.

≠ 0 No sensor discard is permitted.

ICON(7) Selection of cross section library. This option was made obsolete in the UNIX version of the code. The C-shell SANDII script now controls the cross section library selection. The only library supported in this distributed version is the SNLRML dosimetry cross section library. An older ENDF/B-V Dosimetry Library option is available at SNL and labeled as "SANDIA". This older set of cross sections should not be used for any spectrum determinations. It is used within the SNL Radiation Metrology Laboratory (RML) solely to determine the sensitivity of the resulting spectrum to the cross section library.

ICON(8) Not used

ICON(9) Loop control for ICON(1)=3 option. This variable is used to fill the igrand_loop variable and controls the number of outer iterations used in the preliminary spectrum smoothing.

ICON(10) Option to output the sensor response functions of the trial spectrum. Note this option prepares plot interface files which represent the product

of the trial function and the dosimetry reaction cross section versus neutron lethargy.

ICON(11) Selection of the knot array files used in the smoothing algorithm under ICON(1)=3. This option was developed under a VAX version of the code and has not been properly interfaced in the exported UNIX version of the code. This option should not be used.

ICON(12) Option to write the dosimetry cross sections to files in a format compatible with an interface to the MCNP Monte Carlo radiation transport code [9] as scoring functions. The SNL implementation of MCNP has a pre-processor that is capable of automatically inserting these scoring functions (in the SAND-II 640 energy structure). This makes the MCNP input file smaller and more manageable for editing, but ensures high fidelity in the scoring functions. The MCNP option of scoring with the internal point cross sections is not used for many dosimetry applications because the currently distributed MCNP cross sections are based on ENDF/B-V. The location of these MCNP interface files is currently hardwired to "${dirstub}/mcnp_interface/sand_response" in the sigs.f source routine. This location is controlled by the ${dirstub} environmental variable which is set in the sandii C-shell script.

6.3 Specification of Sensor Activities/Responses

The normal SAND-II input format for sensors and activities is still the default input format. However, the RML has found that it is often desirable to have the sensor activity defined on the same line which specifies the sensor reaction identifier. This second, more compact, option is invoked if any character follows the word "FOIL" on the SAND-II card that specifies the number of input sensors. In the RML sample problem for the spr3cc spectrum, the users initials, pjg, are used. Thus when 24 sensors are used, the sensor/foil number specification record appears as:

```
24 foil pjg
```

When this option is invoked, the free-format field following the sensor identification must be the activity and the "ACTS" cards do not appear.

6.4 Trial Spectrum Tabular Input Option

The normal SAND-II input required "**ENER**" and "**FLUX**" cards for the input of the differential number spectrum to be used as a trial function. In SNL-SAND-II a tabular input option is provided. If the spectrum card appears as:

```
spectrum low
```

or

```
spectrum high
```

then a 2*N point energy/spectrum tabulation is permitted, where N is specified on the "**POINTS**" record. A free-format designator is used to read the energy/flux pairs of points.

The energy should typically have units of eV. If the highest input energy point is less than 1.0e+6, the program assumes that the user mistakenly entered the energy grid in units of MeV instead of eV and scales all energy values by 1.0e+6.

6.5 Cover Cross Sections

The current version, when operating in conjunction with the SNLRML cross section compendium, has six cover materials implemented. These materials and their identifiers are defined in Table 1.

Table 1: SNL-SAND-II Cover Identifiers

Cover Identifier	Material Description
Cd	Natural cadmium, containing contributions from all absorption reactions. The cross sections were taken from the JENDL-3 library [10].
B	Natural boron (19.9% ^{10}B, 80.1% ^{11}B atom percents), contains contributions from all absorption reactions. The cross sections were taken from ENDF/B-VI [11].
Au	^{nat}Au, contains contributions from all absorption reactions. The cross sections were taken from the ENDF/B-VI [11] library.
B10	^{10}B, contains contributions from all absorption reactions. The cross sections were taken from the ENDF/B-VI [11] library.
B11	^{11}B, contains contributions from all absorption reactions and the cross section was taken from the ENDF/B-VI [11] library.
B4C	B_4C with a 91.67% (atom percent of the boron present) ^{10}B-enrichment. This cover material contains contributions from all absorption reactions and uses ENDF/B-VI [11] cross sections for ^{10}B, ^{11}B, and ^{nat}C.

The user should be careful of the treatment of cover materials if a different cross section library is interfaced to this version of SAND-II. The order of the cover materials as named in the source code for each of the SNL-SAND-II code modules (CSTAPE, SLTAPE, SLACTS, and SANDII) must agree with the order of cover materials in the associated cross section library. The default cover thicknesses are hardwired in a specific order into the SLACTS acti.f module.

6.6 Input Text Format

The current SNL-SAND-II input processor is case sensitive. Lower-case should be used for all data. An error will be reported if a number is entered with "E" for the exponential term rather than "e". Thus "1.0e+6" is a valid input number but "1.0E+6" would result in a processing error indicating that a data card contains a numeric data item which includes a character other than a numeric digit, decimal, sign, or the letter e. Numbers can also be entered without the "e". Thus "1.0-6" a valid input and is the same as "1.0e-6".

7. Changes in SAND-II Output

The following sections detail the changes in the SAND-II output.

7.1 Level of Output

The current version allows the user to select the level of printout that goes to the {job}.out file. Here, {job} stands for the user input file name that appears as the first argument passed to the C-shell script (the file name of the script is sandii). The output level is controlled by the ICON(3) control parameter described in a previous section.

7.2 Spectrum Integral Parameter Summary

A summary of several useful spectrum integral parameters is provided immediately following the usual summary of the SAND-II quality of fit. A description of these output integral quantities can be found in Reference 12. The descriptions of the baseline neutron irradiation environments in Reference 12 correspond to the spr3cc, scr4, acf9, and tpb13 sample files that are included in Appendix A of this document.

7.3 Analysis of Spectrum Shape

As an aid to the implementation of the outer iteration methodology described in Reference 7, the shape of the final neutron spectrum is analyzed. Structure is identified with respect to location to energy and the severity/prominence of the structure. If the location of the center of the structure corresponds to a recorded resonance peak for a primary sensor used in the analysis, this reaction is associated with the summary of the spectrum shape. The set of recorded resonance peaks can be found/modified in the main program 'sand-ii.f'. The energy and isotope identification is passed to subroutine 'resonance.f' for output in a form compatible with the ACE/gr code.

7.4 ASCII Interface Files

Several ASCII format interface files are created to facilitate use of the SAND-II results in other applications. The following sections describe some of the available interface files. In the following discussion, it is assumed that the input file was named {job}.

{job}.out	The normal output file. This file is not saved, but is converted into the {job}.prt file described below.

{job}.prt — The {job}.out file is passed through the UNIX fpr filter to treat FORTRAN carriage-control conventions and saved as {job}.prt.

{job}.log — This file contains any workstation operating system diagnostic messages and some SNL-SAND-II diagnostics. The file is created by redirection of the UNIX 'stderr' and 'stdout' output streams. It is useful for quick look to determine if the run was successful.

{job}.pun — A packed tabulation of the differential number spectrum for the final spectrum. This format includes 641 pairs of numbers. The first number is the neutron bin lower energy. The second number is the differential number spectrum value and corresponds to the differential flux in the SAND-II solution spectrum printed in the long-print ICON(3) option.

{job}.pun-out — The final SAND-II differential number spectrum in 640 groups in a format suitable for input to a subsequent SAND-II calculation as a new trial function. This means that the file format uses the "**ENER**" and "**FLUX**" card designators expected by the normal SAND-II input definition of a trial spectrum. This spectrum definition corresponds to the SAND-II differential flux that has been normalized to the user-specified value, typically so that the integral above 10 keV is 1.

{job}.pun-sand — This file contains the same data as {job}.pun-kelly but in the format of {job}.pun-out. The output does not use the input trial spectrum bin structure, but always uses 640 bins. This file can be useful for obtaining an explicit listing of the spectrum at points where the normal SAND-II algorithms interpolated a flux.

{job}.pun-kelly — This file is the 640 group SAND-II trial function in a format similar to the {job}.pun file.

{job}.rsp — This file is a DISSPLA TELL-A-GRAPH [13] format file that plots the neutron lethargy versus the dosimetry sensor response. The response is defined as the cross section multiplied by the energy and the differential number spectra. The response has units of b • eV • (n/cm^2). The DISSPLA TELL-A-GRAPH code is a copyrighted commercially available program. Since this file is in ASCI format it can be easily modified to interface with other plotting programs.

{job}.spc — This file is a DISSPLA TELL-A-GRAPH format file that plots the neutron energy versus the dosimetry sensor cross section. The y-axis has units of barns and the x-axis has units of MeV.

xxxx#_yyyy — This file is an MCNP interface file written to the /u4/application/mcnp/sand_response directory. The "xxxx" stands for the SAND-II reaction identifier. The "yyyy" stands for the cover identifier. Several cover identifiers can be used in combination if they are separated by an underline symbol (_), for example xxxx#_yyyy_zzzz.

8. SNL-SAND-II Plot Interface

In addition to the ASCII interface files, automatic plot interfaces are provided for the public domain ACE/gr graphics package [2] and the commercial TempleGraph graphics package [14].

The installation and operation of the ACE/gr graphics package is described in the README file. The plot files produced include:

{job}.plt.xvgr	An ACE/gr interface file for the "-plt" flag plots.
{job}.look"n"	An ACE/gr interface for the "-look" flag plots. The index "n" takes on values from 1 to 4.

To print the plots to a default Postscript printer use the "batchplot" command from the /usr/codes/sandia/sandii/plot directory. "Batchplot" has three modes of operation. If you type "batchplot" without any arguments the command syntax is described. A "-plt" flag prints the summary plot which may include identification of the energy sensitive regions. If a "-look" flag is used, a series of four enlargements of different energy regions of the output spectrum are provided. These enlarged plots are useful for defining the trial function that will be used for the next SAND-II outer iteration loop. If a flag of "-all" is used both the "-plt" and the "-look" plots are produced. The default option is "-all" if no qualifier is given. A sample of these plots for the spr3cc, scr4, acf9, and tpb13 spectra are attached as Appendix B to this memorandum.

The batchplot script prints Postscript to the default printer. If the user wishes to print to a print queue called "special", the following line should be added to the batchplot script:

```
setenv GR_PS_PRSTR "lpr -h -Pspecial"
```

If the user wishes to create a Postscript file rather than send the file to a printer, the following line should be added to the batchplot script:

```
setenv GR_PS_PRSTR "cat >acegr.ps <"
```

When this symbol definition is in effect, the ACE/gr program will produce a Postscript-format file called acegr.ps in the default directory. This file should be renamed as soon as it is created to avoid overwriting it with a second ACE/gr plot.

Since the commercial TempleGraph graphics package is probably not available at most sites that will implement this SNL-SAND-II code, the enclosed scripts have deactivated this option. This was necessary since, in normal operation, the TempleGraph module is automatically activated during a SAND-II run and opened as a window to facilitate user previewing of the spectrum shape. This option will be enhanced in the future to support interactive modification and iteration of the trial spectrum. Interactive definition of the trial function will greatly improve the application of the outer iteration methodology described

in Reference 7. The TempleGraph option can be re-activated by removing the pplan.f and pplan.o files from the file /usr/codes/sandia/snlsand/sandii/source/makefile SCRS and OBJ definitions and adding a LIBS definition that points to the location of the TempleGraph's Partner's Plan linkable object. For the code, as implemented on the SNL workstation sass147.tav.sandia.gov, this line appears as:

```
LIBS=    /u/var/tgraph/partners/libpartII.a-sparcOS4
```

If the above location is not used for the TempleGraph object libraries, then the variable "exec" in the sandii.f file must be changed to point to the correct directory location.

The TempleGraph plot interface files include:

{job}.data	This is a data file for the TempleGraph plot of the differential number flux.
{job}.template	This is a template file for the TempleGraph plot of the differential number flux. The TempleGraph manuals describe the format of the template file.

9. Execution of SNL-SAND-II

To operate the SNL-SAND-II code after installation, code recompilation, and library re-construction, the user should type:

```
sandii test
```

from the SAND-II input directory (/usr/codes/sandia/sandii/input in the earlier example) where "test" is the name of the desired input file. Sample input files corresponding to several of the SNL reactor environments are included in the installed version of SAND-II. These sample input files should have been run as part of the installation checkout. These files will function as examples and should serve to aid the user in constructing his own applicable input files.

10. Planned Code Enhancements

Several code enhancements are planned. These enhancement include:

1 Implementation of an sensor option that corresponds to a combination of existing dosimetry sensors. This option is useful for fission and activation foils that contain contaminants that produce products similar to the main sensor isotope product.

2 Implement the required code for using the SNLRML S-3MEV sensor to input a ^{252}Cf fluence value that corresponds to that used in the transfer calibration of most $^{32}S(n,p)^{32}P$ dosimetry counting systems.

3 Implementation of a smoothing algorithm between SAND-II iterations that will allow easier application of the SAND-II Outer Iteration Methodology [7,8]. Some of this

code appears in the current version, but the option has not been validated and the preliminary results did not meet expectations.

4 Implementation of a interactive feedback between the ACE/gr graphics and the SNL-SAND-II code that would allow graphical modification of the trial spectrum and additional outer iterations. This procedures should greatly reduce the time required for application of the SAND-II Outer Iteration Methodology [7, 8].

5 Automation of the Kelly perturbation methodology [8] to obtain activity-constrained uncertainty bounds on the SAND-II resulting spectrum.

6 Implementation of a statistical fluctuation of the input activities (within specified input bounds representing the activity uncertainty) to obtain another bound on the spectrum uncertainty.

7 Coupling of the SNL-SAND-II input file to the UFO code[15] to allow application of the Backus-Gilbert methodology [16, 17] for specification of the energy-dependent spectrum unfolding uncertainty (both differential fluence magnitude and energy spread).

Future versions of the SNL-SAND-II code will continue to be distributed through RSIC.

11. Use with Sulfur Activation Sensors

A special warning should be given concerning the use of the $^{32}S(n,p)^{32}P$ sensors used in any spectrum unfolding methodology. The cross section used by the unfolding code MUST agree with the cross section used to derive the measured activity. This requirement results from the typical use of a transfer calibration from a benchmark standard field, such as the NIST ^{252}Cf field, to calibrate the counting system. If an activity is reported by a dosimetry laboratory, it has been derived by folding the benchmark standard field spectrum into a $^{32}S(n,p)^{32}P$ cross section. If the SNLRML cross section compendium is used with the SNL-SAND-II code, then the GLUCS [18] or IRDF-90 [19] cross section must be used, NOT the ENDF/B-VI cross section. An error of about 8% will result if the ENDF/B-VI cross section is used for the transfer calibration and the SNLRML dosimetry cross sections are used for the unfolding.

12. Contacts

If users at SNL have problems with the code installation, they should contact P. J. Griffin, J. G. Kelly or J. VanDenburg, organization 6514, at (505) 845-9121 or FAX at (505) 845-3115. We can be reached by e-mail at pjgriff@sandia.gov. Limited phone support can be provided to users outside the DOE laboratories. Additional support requires a Work-For-Others contract.

13. References

[1] W. N. McElroy, S. Berg, T. Crockett, and R. Hawkins, *A Computer-Automated Iterative Method for Neutron Flux Spectral Determination by Foil Activation*, AFWL-TR-67-41, Vol. 1, Air Force Weapons Laboratory, Kirkland, New Mexico, July 1967.

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APPENDIX A

SNL-SAND-II Spectra Characterization For Some Of The SNL Primary Radiation Environments

SNL-SAND-II Run 1:

Environment:	**SPR-III Central Cavity**
File Name:	**SPR3CC**
Shot Date:	**12/1/92**
Facility Shot Number:	**8827**
Run Conditions:	**250 sec @ 1 kwatt**
Dosimetry Position:	**Position in central cavity with RCC cardboard fixture and aluminum honeycomb to attain vertical centerline position. Used cart for experiment insertion.**

```
*** snl 6522 endf/b-vi specialized version of sand-ii ***

control parameters:  0 0 4 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
spline knot control file : fission



Job name = spr3cc
Library  = snlrml

 1 cases
t spr-iii central cavity, shot 8827, 12/1/92
t sand ii spr iii foil set for shot 8827, spr3cav.
t (dec. 1, 1992),fitted trial spectrum, cavity free field.
t
t modification of spr3cav28-nf to fix bump in trial function
t    that can not be substantiated by MCNP transport calculations
t    and looks to be unacceptable if a spectrum differential energy
t    representation
t
t
t convert s32p activity to GLUCS-93 with ENDF/B-VI cf-252 spectrum
t   SAND-II activity ratio for conversion is 3.954e-32/4.278-32 = 0.9242636746
t   MANIPULATE xsec ratio for conversion is 70.45055/76.01238 = 0.9268299453
t   the difference is due to numerical roundoff and interpolation of flux
t   we select the SAND-II activity ratio for RML conversion
t
t
t
t add new fission foil data - normalized to Ni foil in
t Boron ball of original shot
t
t  use boron ball data only doe u235
t  include uncovered data on old foils since data was not taken
t  with new foils
t
t  original data
```

```
t  u235f     1.755-11  cadmium 4.705-3
t  u235f     1.555-11  cadmium 4.705-3 b4c 0.1481
t  u238f     2.317-12  cadmium 4.705-3
t  u238f     2.169-12  cadmium 4.705-3 b4c 0.1481
t  pu239f    2.233-11  cadmium 4.705-3
t  pu239f    2.061-11  cadmium 4.705-3 b4c 0.1481
t
t conversion factors for new foils
t     rmlpu nickel ratio (this/test) = 0.401726, test fission activity = 6.0744-
t     rmldu nickel ratio (this/test) = 0.40758,  test fission activity = 5.3432-
t     rmleu nickel ratio (this/test) = 0.40758,  test fission activity = 3.6010-
t     mass conversion for rmleu foil = 0.8805085   (U par of UO2)
t     mass conversion for rmldu foil = 0.88176613  (U part of UO2)
t     mass conversion for rmlpu foil = 1.14916     (Pu part where 1.0 = Pu239 pa
t
t  use 10% reduction in ni58 inside/outside B4C ball to form adjustment for
t  fission foils.  Note the current SAND model provides ~5% with its
t  exponential attenuation model.  The second 5% is applied by hand
t  to the activities to account for scattering effects.  The boron ball run
t  uses a ni58 foil both inside and outside to confirm identical
t  placement of the dosimetry.
t  In reality cover corrections are foil/sensor and spectrum dependent.
t
t
 iteration   time integrated
 24 foils pjg
 au197g    6.574-18  cadmium 2.587-3
 au197g    7.414-18
 mg24p     1.242-19  cadmium 2.587-3
 fe56p     5.408-19  cadmium 2.587-3
 al27a     6.135-20  cadmium 2.587-3
 fe54p     1.400-20  cadmium 2.587-3
 ni58p     8.752-20  cadmium 2.587-3
 zr902     1.616-21  cadmium 2.587-3
 s32p      2.508-19
 rmleu     1.5003-11  cadmium 4.705-3 b4c 0.1481
 u238f     2.317-12  cadmium 4.705-3
 rmldu     2.2228-12  cadmium 4.705-3 b4c 0.1481
 pu239f    2.233-11  cadmium 4.705-3
```

```
rmlpu     1.9116-11  cadmium 4.705-3 b4c 0.1481
np237f    1.234-11   cadmium 4.705-3
np237f    1.182-11   cadmium 4.705-3 b4c 0.1481
tisc46    7.325-21   cadmiun 2.587-3
tisc47    2.882-19   cadmium 2.587-3
ti48p     8.684-21   cadmium 2.587-3
zn64p     3.882-18   cadmium 2.587-3
co59g     6.923-22   cadmium 2.587-3
cu63g     3.302-18   cadmium 2.587-3
in115n    6.204-17
u235f     1.755-11   cadmium 4.705-3
spectrum tabular
53 points
ener    5.00-8  7.20-8  1.00-7  1.50-7  2.00-7
ener    3.00-7  5.00-7  7.20-7  1.00-6  1.50-6  2.00-6
ener    3.00-6  5.00-6  7.20-6  1.00-5  1.50-5  2.00-5
ener    3.00-5  5.00-5  7.20-5  1.00-4  1.50-4  2.00-4
ener    3.00-4  5.00-4  7.20-4  1.00-3  1.50-3  2.00-3
ener    3.00-3  5.00-3  7.20-3  1.00-2  1.50-2  2.00-2
ener    3.00-2  5.00-2  7.20-2  1.00-1  1.50-1  2.00-1
ener    3.00-1  5.00-1  7.20-1  1.00-0  1.50-0
ener    2.00-0  3.00-0  4.00-0  5.00-0  6.00-0
ener    7.00-0  8.00-0
flux    1.05+3  8.20+2  6.00+2  3.60+2  2.35+2
flux    9.00+1  2.80+1  1.60+1  1.10+1  7.50-0  5.80-0
flux    4.40-0  3.30-0  2.40-0  2.00-0  1.60-0  1.35-0
flux    1.10-0  8.50-1  7.00-1  5.50-1  4.10-1  3.20-1
flux    2.50-1  1.70-1  1.35-1  1.00-1  7.60-2  6.50-2
flux    6.80-2  1.00-1  1.30-1  1.70-1  2.40-1  3.10-1
flux    4.20-1  6.60-1  8.20-1  9.60-1  1.02-0  9.80-1
flux    8.60-1  6.20-1  4.30-1  3.10-1  1.85-1
flux    1.35-1  7.30-2  3.50-2  1.87-2  1.20-2
flux    5.50-3  1.90-3
limit    25
deviation 3.5
discard 3.0
low end thermal
high end fission
norm 0.010
```

plot cards
smooth 5

interim results after 0 iterations

foil reaction			nominal 5.00 percent activity limits (mev) lower	nominal 5.00 percent activity limits (mev) upper	ratio measured to calculated activities	deviation of measured from calculated activity (percent)
s32 (n,p) p32			2.300E+00	7.200E+00	1.0081	0.81
ni58 (n,p) co58	Cd		1.900E+00	7.400E+00	1.0469	4.69
mg24 (n,p) na24	Cd		6.500E+00	1.160E+01	0.9541	-4.59
al27 (n,a) na24	Cd		6.400E+00	1.200E+01	1.0231	2.31
tinat (n,x) sc46	Cd		3.800E+00	9.300E+00	1.0673	6.73
ti48 (n,p) sc48	Cd		5.900E+00	1.230E+01	1.0788	7.88
tinat (n,x) sc47	Cd		1.600E+00	7.500E+00	0.9462	-5.38
fe54 (n,p) mn54	Cd		2.300E+00	7.400E+00	0.9809	-1.91
fe56 (n,p) mn56	Cd		5.500E+00	1.120E+01	1.0100	1.00
co59 (n,g) co60	Cd		1.200E-04	1.700E+00	1.0650	6.50
cu63 (n,g) cu64	Cd		2.100E-02	2.400E+00	0.9504	-4.96
zn64 (n,p) cu64	Cd		2.400E+00	7.400E+00	0.9686	-3.14
zr90 (n,2n) zr89	Cd		1.270E+01	1.750E+01	1.0154	1.54
in115(n,n)in115m			1.000E+00	5.900E+00	1.0169	1.69
au197(n,g) au198	Cd		4.750E-06	1.600E+00	0.9556	-4.44
au197(n,g) au198			1.100E-07	1.600E+00	1.0104	1.04
u235 (n,f) fp	Cd		6.300E-02	4.000E+00	0.9902	-0.98
u238 (n,f) fp	Cd		1.400E+00	6.600E+00	1.0346	3.46
np237(n,f) fp	Cd		5.250E-01	5.200E+00	0.9983	-0.17
np237(n,f) fp	Cd	B4C	5.250E-01	5.200E+00	0.9989	-0.11
pu239(n,f) fp	Cd		8.800E-02	4.200E+00	0.9410	-5.90
u235 (n,f) rml	Cd	B4C	8.400E-02	4.200E+00	0.9886	-1.14
u238 (n,f) rml	Cd	B4C	1.400E+00	6.600E+00	1.0248	2.48
pu239(n,f) rml	Cd	B4C	1.100E-01	4.400E+00	0.9260	-7.40

standard deviation of measured activities (percent) 4.18

average total flux (above 1.00E-02 mev) 1.399E+13

loop 1 iteration 0 4.1840

loop 1 iteration 1 3.7032

loop 1 iteration 2 3.5102

solution has been achieved.

standard deviation of measured-to-calculated activity ratios is less than 3.50percent./

solution results obtained after 3 iterations

foil reaction	measured activity (dps/nucleus)	calculated activity (dps/nucleus)	nominal 5.00 percent activity limits (mev) lower	nominal 5.00 percent activity limits (mev) upper	ratio measured to calculated activities	deviation of measured from calculated activity (percent)
s32 (n,p) p32	2.508E-19	2.501E-19	2.300E+00	7.300E+00	1.003	0.2825
ni58 (n,p) co58 Cd	8.752E-20	8.413E-20	1.900E+00	7.400E+00	1.040	4.030
mg24 (n,p) na24 Cd	1.242E-19	1.324E-19	6.500E+00	1.160E+01	0.9383	-6.170
al27 (n,a) na24 Cd	6.135E-20	6.107E-20	6.400E+00	1.200E+01	1.005	0.4599
tinat (n,x) sc46 Cd	7.325E-21	6.981E-21	3.800E+00	9.300E+00	1.049	4.923
ti48 (n,p) sc48 Cd	8.684E-21	8.210E-21	5.900E+00	1.230E+01	1.058	5.769
tinat (n,x) sc47 Cd	2.882E-19	3.061E-19	1.600E+00	7.500E+00	0.9416	-5.844
fe54 (n,p) mn54 Cd	1.400E-20	1.437E-20	2.300E+00	7.400E+00	0.9739	-2.605
fe56 (n,p) mn56 Cd	5.408E-19	5.465E-19	5.500E+00	1.120E+01	0.9895	-1.051
co59 (n,g) co60 Cd	6.923E-22	6.721E-22	1.150E-04	1.700E+00	1.030	3.006
cu63 (n,g) cu64 Cd	3.302E-18	3.374E-18	2.100E-02	2.400E+00	0.9786	-2.140
zn64 (n,p) cu64 Cd	3.882E-18	4.032E-18	2.400E+00	7.400E+00	0.9629	-3.712

zr90 (n,2n) zr89 Cd	1.616E-21	1.619E-21	1.270E+01	1.750E+01	0.9984	-0.1608
in115(n,n)in115m	6.204E-17	6.094E-17	1.000E+00	5.900E+00	1.018	1.810
au197(n,g) au198 Cd	6.574E-18	6.699E-18	4.750E-06	1.600E+00	0.9813	-1.870
au197(n,g) au198	7.414E-18	7.190E-18	8.400E-08	1.600E+00	1.031	3.119
u235 (n,f) fp Cd	1.755E-11	1.734E-11	6.300E-02	4.100E+00	1.012	1.210
u238 (n,f) fp Cd	2.317E-12	2.245E-12	1.400E+00	6.600E+00	1.032	3.191
np237(n,f) fp Cd	1.234E-11	1.222E-11	5.250E-01	5.300E+00	1.010	0.9581
np237(n,f) fp Cd B4C	1.182E-11	1.170E-11	5.500E-01	5.300E+00	1.010	1.022
pu239(n,f) fp Cd	2.233E-11	2.325E-11	8.800E-02	4.300E+00	0.9604	-3.956
u235 (n,f) rml Cd B4C	1.500E-11	1.485E-11	8.400E-02	4.200E+00	1.010	1.026
u238 (n,f) rml Cd B4C	2.223E-12	2.174E-12	1.400E+00	6.600E+00	1.023	2.254
pu239(n,f) rml Cd B4C	1.912E-11	2.024E-11	1.150E-01	4.500E+00	0.9445	-5.552
						------

standard deviation of measured activities (percent) 3.390

---

response analysis - loop = 1 iteration = 3

response function	dose
fluence (n/cm**2)	0.1369761E+14
kerma (rad-tissue)	29237.31
cp dose to elem-57 (rad-tissue)	32953.93
dose eqv. (rem)	348054.5
dose to elem-57 from h-1(n,g)h-2 (rad-tissue)	3470.135
ansi and ncrp dose (rem)	364748.0

---

spectrum characterization

total fluence (n/cm**2)	1.3697612E+13	
fluence > 10 kev	1.3677593E+13	(0.9985385)

fluence > 3 Mev	1.4700893E+12	(0.1073245)
fluence < 1 eV	2.4819794E+09	(1.8119796E-04)
avg. energy (mev)	1.257954	
HP-ASTM E722-85	0.8952391	
(ASTM Si damage function)		
HP-ASTM E722-93	0.8211282	
(ENDF-6 Si damage function)		
HP-10kev E722-85	0.8965495	
(ASTM Si damage function)		
HP-10kev E722-93	0.8223301	
(ENDF-6 Si damage function)		
SP	9.303920	
(F[>10 kev]/F[>3 MeV)])		
SP	9.317537	
(F[tot]/F[>3 MeV)])		
sulfer cross section (mb)	302.3892	
(spectrum averaged, > 3 mev)		
nickel cross section (mb)	505.4932	
(spectrum averaged, > 3 mev)		
sulfer cross section (mb)	32.45376	
(spectrum averaged, > total)		
nickel cross section (mb)	54.25180	
(spectrum averaged, total)		
gaas 1 mev fluence	1.1832524E+13	(0.8638384)
(ref-sig[gaas] = 70 mev-mb)		
silicon 1 mev fluence	1.1247595E+13	(0.8211354)
(ref-sig[si] = 95 mev-mb)		
old ASTM Si 1 mev flu.	1.2262639E+13	(0.8952392)
(ref-sig[si] = 95 mev-mb)		
S32 Act. -dps/gm meas-ENDF	305819.5	(2.2326480E-08)
S32 Act. - Bq/atom meas.	2.5080000E-19	(1.8309760E-32)
S32 Act. - Bq/atom calc.	2.5009335E-19	(1.8258172E-32)
252-Cf Eq. Flu. S32 Meas.-n/cm2	6.3463542E+12	
252-Cf Eq. Flu. S32 Calc.-n/cm2	6.3284723E+12	
Ni58 Act. - Bq/atom meas.	8.7520000E-20	(6.3894348E-33)
Ni58 Act. - Bq/atom calc.	8.4129878E-20	(6.1419374E-33)

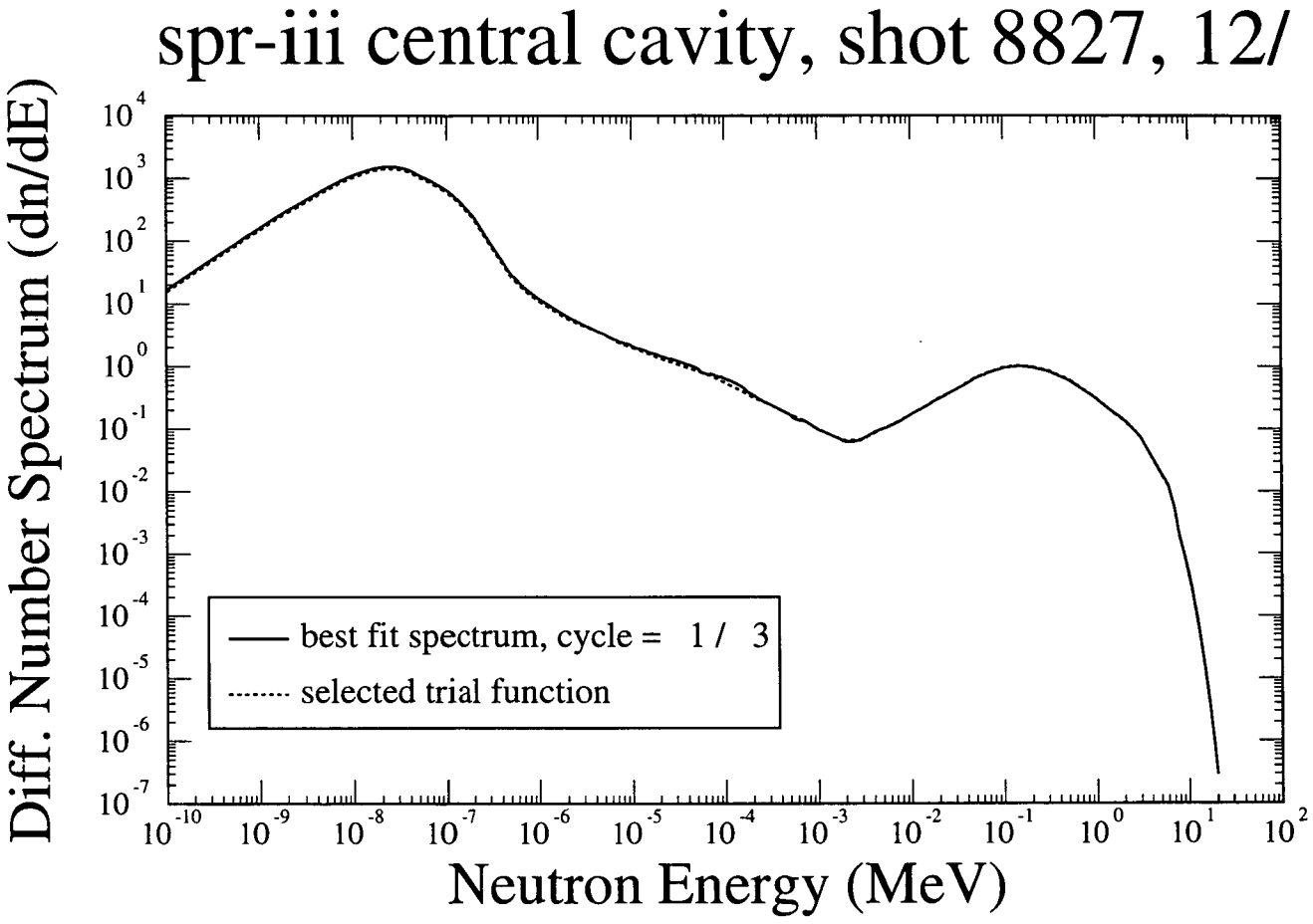

Figure A-1: SPR3CC Differential Number Distribution

SNL-SAND-II Run 2:

Environment:	**SPR-III 17" Leakage**
File Name:	**SCR4**
Shot Date:	**10/5/88**
Facility Shot Number:	**6338**
Run Conditions:	**1000 sec @ 10 kwatt**
Dosimetry Position:	**Dosimetry on curved aluminum plate located at reactor centerline. The azimuthal position is fixed to along the line through the copper control rod.**

```
*** snl 6522 endf/b-vi specialized version of sand-ii ***

control parameters:  0 0 4 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
spline knot control file : fission



Job name = scr4
Library  = snlrml

 1 cases
t SPR-III 17" leakage opposite cu control rod, shot 6338, 10-5-88
t   17" leakage opposite cu control rod
t (mar. 27, 1984) with spr317 trial spectrum, free field.
t
t convert s32p activity to GLUCS-93 with ENDF/B-VI cf-252 spectrum
t   SAND-II activity ratio for conversion is 3.954e-32/4.278-32 = 0.9242636746
t   MANIPULATE xsec ratio for conversion is 70.45055/76.01238 = 0.9268299453
t   the difference is due to numerical roundoff and interpolation of flux
t   we select the SAND-II activity ratio for RML conversion
t
 iteration   time integrated
 18 foils
 au197g    cadmium 2.587-3
 au197g
 fe56p     cadmium 2.587-3
 mn55g     cadmium 2.587-3
 mg24p     cadmium 2.587-3
 al27a     cadmium 2.587-3
 ni58p     cadmium 2.587-3
 s32p
 na23g     cadmium 4.705-3
 na23g
 u235f     b4c 0.1481 cadmium 4.705-3
 u238f     b4c 0.1481 cadmium 4.705-3
 pu239f    b4c 0.1481 cadmium 4.705-3
 np237f    b4c 0.1481 cadmium 4.705-3
```

```
fe54p     cadmium 2.587-3
co59g     cadmium 2.587-3
sc45g     cadmium 2.587-3
ti48p     cadmium 2.587-3
acts 1.208-16 1.410-16 1.132-18 3.784-17 2.807-19
acts 1.340-19 1.814-19
acts 5.319-19
acts 2.358-19 7.022-19
acts 3.029-11 4.604-12 4.171-11 2.505-11
acts 3.191-20 7.982-21 5.687-20 1.902-20
spectrum tabular
41 points
ener    3.00-7  5.00-7  7.00-7  1.00-6  2.00-6
ener    3.00-6  5.00-6  7.00-6  1.00-5  2.00-5
ener    3.00-5  5.00-5  7.00-5  1.00-4  2.00-4
ener    3.00-4  5.00-4  7.00-4  1.00-3  2.00-3
ener    3.00-3  5.00-3  7.00-3  1.00-2  2.00-2
ener    3.00-2  5.00-2  7.00-2  1.00-1  2.00-1
ener    3.00-1  5.00-1  7.00-1  1.00-0  1.50-0
ener    2.00-0  3.00-0  4.00-0  5.00-0  6.00-0  8.00-0
flux    3.40+3  1.75+3  1.20+3  8.50+2  4.40+2
flux    2.90+2  1.75+2  1.20+2  9.10+1  4.50+1
flux    2.90+1  1.75+1  1.30+1  9.10-0  4.90-0
flux    3.40-0  1.90-0  1.40-0  9.80-1  5.20-1
flux    4.10-1  3.50-1  3.40-1  3.50-1  4.20-1
flux    5.00-1  7.00-1  9.30-1  1.00-0  9.50-1
flux    8.00-1  5.20-1  3.60-1  2.80-1  2.05-1
flux    1.45-1  7.40-2  4.10-2  2.40-2  1.30-2  2.25-3
limit 50
deviation 2.00
discard 3.0
low end thermal
high end fission
norm 0.010
plot cards
smooth 5
```

interim results after 0 iterations

foil reaction		nominal 5.00 percent activity limits (mev) lower	nominal 5.00 percent activity limits (mev) upper	ratio measured to calculated activities	deviation of measured from calculated activity (percent)
s32 (n,p) p32		2.300E+00	7.300E+00	0.9736	-2.64
ni58 (n,p) co58	Cd	2.000E+00	7.400E+00	0.9924	-0.76
na23 (n,g) na24	Cd	7.200E-07	2.100E+00	0.9435	-5.65
na23 (n,g) na24		7.600E-09	8.400E-01	1.0622	6.22
mg24 (n,p) na24	Cd	6.500E+00	1.170E+01	0.9968	-0.32
al27 (n,a) na24	Cd	6.400E+00	1.210E+01	1.0170	1.70
sc45 (n,g) sc46	Cd	4.750E-07	1.000E+00	0.9806	-1.94
ti48 (n,p) sc48	Cd	5.900E+00	1.240E+01	1.0865	8.65
mn55 (n,g) mn56	Cd	6.000E-07	8.000E-01	0.9938	-0.62
fe54 (n,p) mn54	Cd	2.300E+00	7.400E+00	1.0166	1.66
fe56 (n,p) mn56	Cd	5.400E+00	1.130E+01	0.9870	-1.30
co59 (n,g) co60	Cd	7.600E-07	2.800E-01	0.9113	-8.87
au197(n,g) au198	Cd	4.000E-06	2.100E-01	0.9890	-1.10
au197(n,g) au198		3.200E-08	1.700E-01	1.0060	0.60
u235 (n,f) fp	B4CCd	6.900E-02	4.400E+00	0.9741	-2.59
u238 (n,f) fp	B4CCd	1.400E+00	6.600E+00	1.0080	0.80
np237(n,f) fp	B4CCd	5.500E-01	5.400E+00	1.0705	7.05
pu239(n,f) fp	B4CCd	9.600E-02	4.600E+00	0.9911	-0.89

standard deviation of measured activities (percent) 4.22

average total flux (above 1.00E-02 mev) 2.686E+13

loop 1 iteration 0 4.2186

loop 1 iteration 1 3.0098

loop	1	iteration	2	2.6975
loop	1	iteration	3	2.5465
loop	1	iteration	4	2.4468
loop	1	iteration	5	2.3722
loop	1	iteration	6	2.3130
loop	1	iteration	7	2.2639
loop	1	iteration	8	2.2222
loop	1	iteration	9	2.1855
loop	1	iteration	10	2.1528
loop	1	iteration	11	2.1228
loop	1	iteration	12	2.0952
loop	1	iteration	13	2.0693
loop	1	iteration	14	2.0449
loop	1	iteration	15	2.0218

solution has been achieved.
standard deviation of measured-to-calculated activity ratios is less than 2.00percent./
solution results obtained after 16 iterations

foil reaction	measured activity (dps/nucleus)	calculated activity (dps/nucleus)	nominal 5.00 percent activity limits (mev) lower	nominal 5.00 percent activity limits (mev) upper	ratio measured to calculated activities	deviation of measured from calculated activity (percent)
s32 (n,p) p32	5.319E-19	5.411E-19	2.300E+00	7.300E+00	0.9831	-1.691
ni58 (n,p) co58 Cd	1.814E-19	1.821E-19	1.900E+00	7.400E+00	0.9961	-0.3912
na23 (n,g) na24 Cd	2.358E-19	2.364E-19	6.900E-07	2.200E+00	0.9973	-0.2660
na23 (n,g) na24	7.022E-19	7.020E-19	7.200E-09	8.000E-01	1.000	23.019E-03
mg24 (n,p) na24 Cd	2.807E-19	2.868E-19	6.500E+00	1.180E+01	0.9788	-2.124
al27 (n,a) na24 Cd	1.340E-19	1.355E-19	6.400E+00	1.220E+01	0.9891	-1.088
sc45 (n,g) sc46 Cd	5.687E-20	5.636E-20	4.750E-07	1.100E+00	1.009	0.8979
ti48 (n,p) sc48 Cd	1.902E-20	1.799E-20	5.900E+00	1.260E+01	1.057	5.745
mn55 (n,g) mn56 Cd	3.784E-17	3.787E-17	5.750E-07	8.400E-01	0.9993	-74.446E-03
fe54 (n,p) mn54 Cd	3.191E-20	3.117E-20	2.300E+00	7.500E+00	1.024	2.373

fe56 (n,p)	mn56	Cd	1.132E-18	1.162E-18	5.500E+00	1.150E+01	0.9741	-2.593
co59 (n,g)	co60	Cd	7.982E-21	7.989E-21	6.900E-07	3.400E-01	0.9992	-81.384E-03
au197(n,g)	au198	Cd	1.208E-16	1.208E-16	4.000E-06	2.100E-01	1.000	37.909E-03
au197(n,g)	au198		1.410E-16	1.412E-16	2.800E-08	1.500E-01	0.9989	-0.1145
u235 (n,f)	fp	B4CCd	3.029E-11	3.081E-11	7.200E-02	4.400E+00	0.9830	-1.703
u238 (n,f)	fp	B4CCd	4.604E-12	4.650E-12	1.400E+00	6.600E+00	0.9901	-0.9907
np237(n,f)	fp	B4CCd	2.505E-11	2.434E-11	5.750E-01	5.300E+00	1.029	2.897
pu239(n,f)	fp	B4CCd	4.171E-11	4.207E-11	1.000E-01	4.600E+00	0.9914	-0.8567

------

standard deviation of measured activities (percent) 2.000

---

response analysis - loop = 1 iteration = 16

response function	dose
fluence (n/cm**2)	0.2699855E+14
kerma (rad-tissue)	59096.36
cp dose to elem-57 (rad-tissue)	67198.90
dose eqv. (rem)	696092.5
dose to elem-57 from h-1(n,g)h-2 (rad-tissue)	6712.248
ansi and ncrp dose (rem)	729588.6

---

spectrum characterization

total fluence (n/cm**2)	2.6998548E+13	
fluence > 10 kev	2.6615822E+13	(0.9858242)
fluence > 3 Mev	3.2028880E+12	(0.1186319)
fluence < 1 eV	1.2062399E+11	(4.4677956E-03)
avg. energy (mev)	1.337955	
HP-ASTM E722-85	0.9117525	

(ASTM Si damage function)		
HP-ASTM E722-93	0.8351308	
(ENDF-6 Si damage function)		
HP-10kev E722-85	0.9248631	
(ASTM Si damage function)		
HP-10kev E722-93	0.8471395	
(ENDF-6 Si damage function)		
SP	8.309945	
(F[>10 kev]/F[>3 MeV)])		
SP	8.429439	
(F[tot]/F[>3 MeV)])		
sulfer cross section (mb)	300.2650	
(spectrum averaged, > 3 mev)		
nickel cross section (mb)	502.2347	
(spectrum averaged, > 3 mev)		
sulfer cross section (mb)	35.62100	
(spectrum averaged, > total)		
nickel cross section (mb)	59.58104	
(spectrum averaged, total)		
gaas 1 mev fluence	2.3524815E+13	(0.8713363)
(ref-sig[gaas] = 70 mev-mb)		
silicon 1 mev fluence	2.2547985E+13	(0.8351554)
(ref-sig[si] = 95 mev-mb)		
old ASTM Si 1 mev flu.	2.4615995E+13	(0.9117525)
(ref-sig[si] = 95 mev-mb)		
S32 Act. -dps/gm meas-ENDF	648586.1	(2.4022997E-08)
S32 Act. - Bq/atom meas.	5.3190004E-19	(1.9701061E-32)
S32 Act. - Bq/atom calc.	5.4105191E-19	(2.0040038E-32)
252-Cf Eq. Flu. S32 Meas.-n/cm2	1.3459433E+13	
252-Cf Eq. Flu. S32 Calc.-n/cm2	1.3691011E+13	
Ni58 Act. - Bq/atom meas.	1.8140001E-19	(6.7188803E-33)
Ni58 Act. - Bq/atom calc.	1.8211238E-19	(6.7452658E-33)

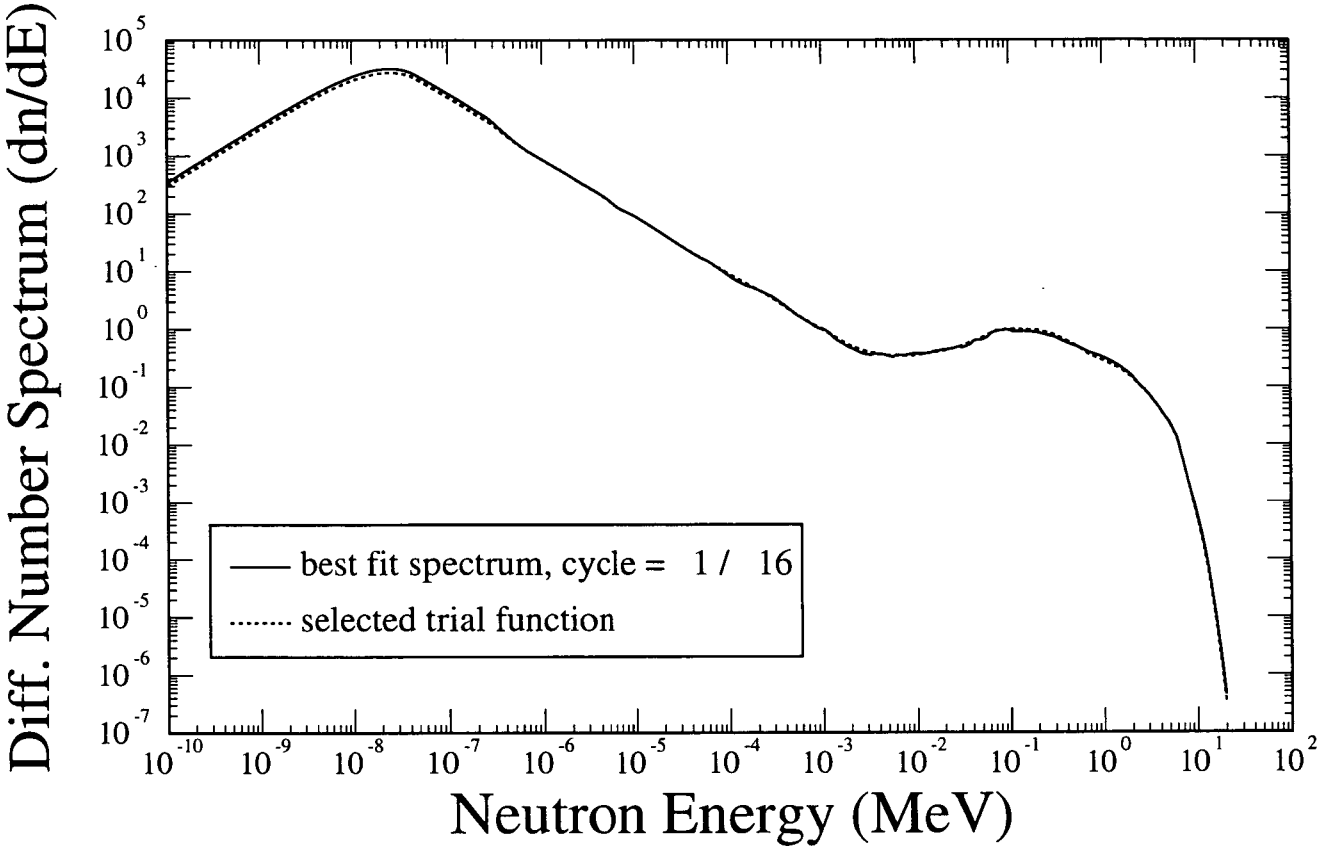

Figure A-2: SCR4 Differential Number Distribution

SNL-SAND-II Run 3:

Environment:	**ACRR Central Cavity**
File Name:	**ACF9**
Shot Date:	**7/14/92**
Facility Shot Number:	**5407**
Run Conditions:	**100sec @ 150 kwatt**
Dosimetry Position:	**Dosimetry fixed on cardboard fixture with in small aluminum frame. Aluminum honeycomb was used to place the dosimetry along the reactor centerline. This run was performed in two parts, 65 and 35 seconds respectively.**

```
*** snl 6522 endf/b-vi specialized version of sand-ii ***

control parameters:  0 0 4 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
spline knot control file : fission


Job name = acf9
Library  = snlrml

 1 cases
t acrr central cavity, shot #5407, 7/14/92
t (jul. 14, 1992), acf.
t
t convert s32p activity to GLUCS-93 with ENDF/B-VI cf-252 spectrum
t   SAND-II activity ratio for conversion is 3.954e-32/4.278-32 = 0.9242636746
t   MANIPULATE xsec ratio for conversion is 70.45055/76.01238 = 0.9268299453
t   the difference is due to numerical roundoff and interpolation of flux
t   we select the SAND-II activity ratio for RML conversion
t
t fe58g from jef
t  supress fe58gjef    cadmium 2.587-3
t  acts 2.698-18
t
t
 iteration   time integrated
 24 foils
 si1mev
 au197g
 au197g    cadmium 2.587-3
 mn55g     cadmium 2.587-3
 pu239f    b4c 0.1481 cadmium 4.705-3
 u235f     b4c 0.1481 cadmium 4.705-3
 np237f    b4c 0.1481 cadmium 4.705-3
 u238f     b4c 0.1481 cadmium 4.705-3
 fe54p     cadmium 2.587-3
 ni58p     cadmium 2.587-3
```

```
s32p
mg24p     cadmium 2.587-3
fe56p     cadmium 2.587-3
al27a     cadmium 2.587-3
zr902     cadmium 2.587-3
co59g     cadmium 2.587-3
na23g
na23g     cadmium 2.587-3
sc45g     cadmium 2.587-3
ti46p     cadmium 2.587-3
ti47p     cadmium 2.587-3
ti48p     cadmium 2.587-3
zn64p     cadmium 2.587-3
cu63g     cadmium 2.587-3
acts 1.468+14
acts 5.891-14 5.183-14 9.503-15
acts 3.448-10 3.230-10 1.633-10 2.986-11
acts 1.832-19 1.098-18
acts 3.223-18
acts 1.423-18
acts 6.017-18 7.187-19 2.111-20 2.500-18
acts 1.906-16 4.319-17 1.307-17 8.659-20
acts 4.103-18 1.021-19 5.043-17 8.368-16
spectrum tabular
45 points
ener    5.00-8  7.00-8  1.00-7  2.00-7
ener    3.00-7  5.00-7  7.00-7  1.00-6  2.00-6
ener    3.00-6  5.00-6  7.00-6  1.00-5  2.00-5
ener    3.00-5  5.00-5  7.00-5  1.00-4  2.00-4
ener    3.00-4  5.00-4  7.00-4  1.00-3  2.00-3
ener    3.00-3  5.00-3  7.00-3  1.00-2  2.00-2
ener    3.00-2  5.00-2  7.00-2  1.00-1  2.00-1
ener    3.00-1  5.00-1  7.00-1  1.00-0  1.50-0
ener    2.00-0  3.00-0  4.00-0  5.00-0  6.00-0  8.00-0
flux    8.90+5  6.50+5  4.45+5  2.20+5
flux    1.50+5  9.00+4  6.60+4  4.70+4  2.45+4
flux    1.60+4  9.80+3  6.80+3  4.70+3  2.10+3
flux    1.25+3  7.50+2  5.20+2  3.20+2  1.75+2
flux    1.20+2  7.50+1  5.70+1  4.20+1  2.20+1
```

```
flux    1.65+1  1.15+1  8.40-0  6.50-0  4.00-0
flux    3.00-0  2.10-0  1.70-0  1.30-0  8.00-1
flux    6.00-1  4.00-1  3.10-1  2.30-1  1.70-1
flux    1.25-1  7.00-2  3.30-2  1.30-2  5.50-3  1.50-3
limit    50
deviation 4.0
discard 3.0
low end thermal
high end fission
norm 0.010
plot cards
smooth 5
```

interim results after 0 iterations

foil reaction	nominal 5.00 percent activity limits (mev) lower	nominal 5.00 percent activity limits (mev) upper	ratio measured to calculated activities	deviation of measured from calculated activity (percent)
s32 (n,p) p32	2.300E+00	7.100E+00	0.9520	-4.80
ni58 (n,p) co58 Cd	1.900E+00	7.300E+00	0.9875	-1.25
na23 (n,g) na24	6.600E-09	2.550E-03	0.9771	-2.29
na23 (n,g) na24 Cd	4.500E-07	3.400E-03	0.9381	-6.19
mg24 (n,p) na24 Cd	6.600E+00	1.180E+01	0.9782	-2.18
al27 (n,a) na24 Cd	6.600E+00	1.220E+01	1.0402	4.02
si-28 (n,1mev) x	1.900E-01	4.700E+00	0.9548	-4.52
sc45 (n,g) sc46 Cd	4.250E-07	4.250E-03	0.9840	-1.60
ti46 (n,p) sc46 Cd	3.600E+00	9.500E+00	1.1602	16.02
ti47 (n,p) sc47 Cd	1.600E+00	7.300E+00	0.9900	-1.00
ti48 (n,p) sc48 Cd	6.000E+00	1.250E+01	1.1562	15.62
mn55 (n,g) mn56 Cd	5.000E-07	1.150E-03	0.9183	-8.17
fe54 (n,p) mn54 Cd	2.200E+00	7.300E+00	0.9777	-2.23
fe56 (n,p) mn56 Cd	5.500E+00	1.160E+01	1.1068	10.68
co59 (n,g) co60 Cd	6.000E-07	1.425E-04	0.9524	-4.76

cu63 (n,g) cu64	Cd	5.250E-07	7.600E-02	1.0157	1.57
zn64 (n,p) cu64	Cd	2.400E+00	7.300E+00	0.9419	-5.81
zr90 (n,2n) zr89	Cd	1.270E+01	1.750E+01	1.0158	1.58
au197(n,g) au198		3.600E-08	5.750E-06	1.0121	1.21
au197(n,g) au198	Cd	4.000E-06	6.000E-06	1.0055	0.55
u235 (n,f) fp	B4CCd	1.800E-03	3.400E+00	1.0156	1.56
u238 (n,f) fp	B4CCd	1.400E+00	6.000E+00	0.9633	-3.67
np237(n,f) fp	B4CCd	5.500E-01	4.700E+00	1.0097	0.97
pu239(n,f) fp	B4CCd	3.800E-03	3.800E+00	0.9468	-5.32

standard deviation of measured activities (percent) 6.28

average total flux (above 1.00E-02 mev) 2.247E+14

loop 1 iteration 0 6.2822

loop 1 iteration 1 4.4663

loop 1 iteration 2 4.1068

solution has been achieved.

standard deviation of measured-to-calculated activity ratios is less than 4.00percent./

solution results obtained after 3 iterations

foil reaction	measured activity (dps/nucleus)	calculated activity (dps/nucleus)	nominal 5.00 percent activity limits (mev) lower	nominal 5.00 percent activity limits (mev) upper	ratio measured to calculated activities	deviation of measured from calculated activity (percent)
s32 (n,p) p32	3.223E-18	3.335E-18	2.300E+00	7.200E+00	0.9665	-3.347
ni58 (n,p) co58 Cd	1.098E-18	1.100E-18	1.900E+00	7.400E+00	0.9977	-0.2263

na23 (n,g) na24		1.906E-16	1.908E-16	6.600E-09	2.400E-03	0.9992	-81.474E-03
na23 (n,g) na24	Cd	4.319E-17	4.422E-17	4.500E-07	3.400E-03	0.9766	-2.337
mg24 (n,p) na24	Cd	1.423E-18	1.559E-18	6.500E+00	1.170E+01	0.9129	-8.708
al27 (n,a) na24	Cd	7.187E-19	7.407E-19	6.500E+00	1.210E+01	0.9703	-2.971
si-28 (n,1mev) x		1.468E+14	1.497E+14	1.900E-01	4.800E+00	0.9804	-1.963
sc45 (n,g) sc46	Cd	1.307E-17	1.283E-17	4.250E-07	4.500E-03	1.018	1.836
ti46 (n,p) sc46	Cd	8.659E-20	7.822E-20	3.700E+00	9.600E+00	1.107	10.70
ti47 (n,p) sc47	Cd	4.103E-18	4.080E-18	1.600E+00	7.500E+00	1.006	0.5657
ti48 (n,p) sc48	Cd	1.021E-19	9.491E-20	6.000E+00	1.250E+01	1.076	7.577
mn55 (n,g) mn56	Cd	9.503E-15	9.610E-15	5.000E-07	1.150E-03	0.9889	-1.111
fe54 (n,p) mn54	Cd	1.832E-19	1.860E-19	2.200E+00	7.400E+00	0.9847	-1.531
fe56 (n,p) mn56	Cd	6.017E-18	5.864E-18	5.500E+00	1.160E+01	1.026	2.607
co59 (n,g) co60	Cd	2.500E-18	2.501E-18	6.000E-07	1.425E-04	0.9994	-58.925E-03
cu63 (n,g) cu64	Cd	8.368E-16	8.278E-16	5.250E-07	7.200E-02	1.011	1.082
zn64 (n,p) cu64	Cd	5.043E-17	5.295E-17	2.400E+00	7.400E+00	0.9524	-4.763
zr90 (n,2n) zr89	Cd	2.111E-20	2.117E-20	1.270E+01	1.750E+01	0.9974	-0.2629
au197(n,g) au198		5.891E-14	5.862E-14	3.800E-08	5.500E-06	1.005	0.4907
au197(n,g) au198	Cd	5.183E-14	5.207E-14	4.000E-06	5.750E-06	0.9953	-0.4663
u235 (n,f) fp	B4CCd	3.230E-10	3.122E-10	1.800E-03	3.400E+00	1.035	3.459
u238 (n,f) fp	B4CCd	2.986E-11	3.010E-11	1.400E+00	6.200E+00	0.9920	-0.8017
np237(n,f) fp	B4CCd	1.633E-10	1.577E-10	5.500E-01	4.800E+00	1.036	3.552
pu239(n,f) fp	B4CCd	3.448E-10	3.564E-10	3.800E-03	3.800E+00	0.9676	-3.242
							------

standard deviation of measured activities (percent) 3.908

---

response analysis - loop = 1 iteration = 3

response function	dose
fluence (n/cm**2)	0.3505201E+15
kerma (rad-tissue)	401297.4
cp dose to elem-57 (rad-tissue)	453061.4
dose eqv. (rem)	4801317.

```
dose to elem-57 from h-1(n,g)h-2 (rad-tissue)          95531.10
ansi and ncrp dose (rem)                               4913262.

 ---------------------------------------------------------------------------------------------------------

 spectrum characterization


 total fluence (n/cm**2)            3.5052017E+14
 fluence > 10 kev                   2.2017974E+14     (  0.6281514     )
 fluence >  3 Mev                   1.9464955E+13     (  5.5531628E-02 )
 fluence < 1 eV                     4.0990933E+13     (  0.1169432     )
 avg. energy (mev)                  0.6594403
 HP-ASTM E722-85                    0.4652211
    (ASTM Si damage function)
 HP-ASTM E722-93                    0.4267116
    (ENDF-6 Si damage function)
 HP-10kev E722-85                   0.7406195
    (ASTM Si damage function)
 HP-10kev E722-93                   0.6793134
    (ENDF-6 Si damage function)
 SP                                  11.31160
    (F[>10 kev]/F[>3 MeV)])
 SP                                  18.00776
    (F[tot]/F[>3 MeV)])
 sulfer cross section (mb)           304.5098
    (spectrum averaged, > 3 mev)
 nickel cross section (mb)           499.3938
    (spectrum averaged, > 3 mev)
 sulfer cross section (mb)           16.90993
    (spectrum averaged, > total)
 nickel cross section (mb)           27.73215
    (spectrum averaged, total)
 gaas 1 mev fluence                 1.6528472E+14     (  0.4715413     )
    (ref-sig[gaas] = 70 mev-mb)
 silicon 1 mev fluence              1.4973991E+14     (  0.4271934     )
    (ref-sig[si] = 95 mev-mb)
 old ASTM Si 1 mev flu.             1.6306939E+14     (  0.4652211     )
    (ref-sig[si] = 95 mev-mb)
```

S32 Act. -dps/gm meas-ENDF	3930048.	(1.1212046E-08)
S32 Act. - Bq/atom meas.	3.2229999E-18	(9.1949056E-33)
S32 Act. - Bq/atom calc.	3.3346244E-18	(9.5133595E-33)
252-Cf Eq. Flu. S32 Meas.-n/cm2	8.1556211E+13	
252-Cf Eq. Flu. S32 Calc.-n/cm2	8.4380807E+13	
Ni58 Act. - Bq/atom meas.	1.0980000E-18	(3.1324871E-33)
Ni58 Act. - Bq/atom calc.	1.1004907E-18	(3.1395930E-33)

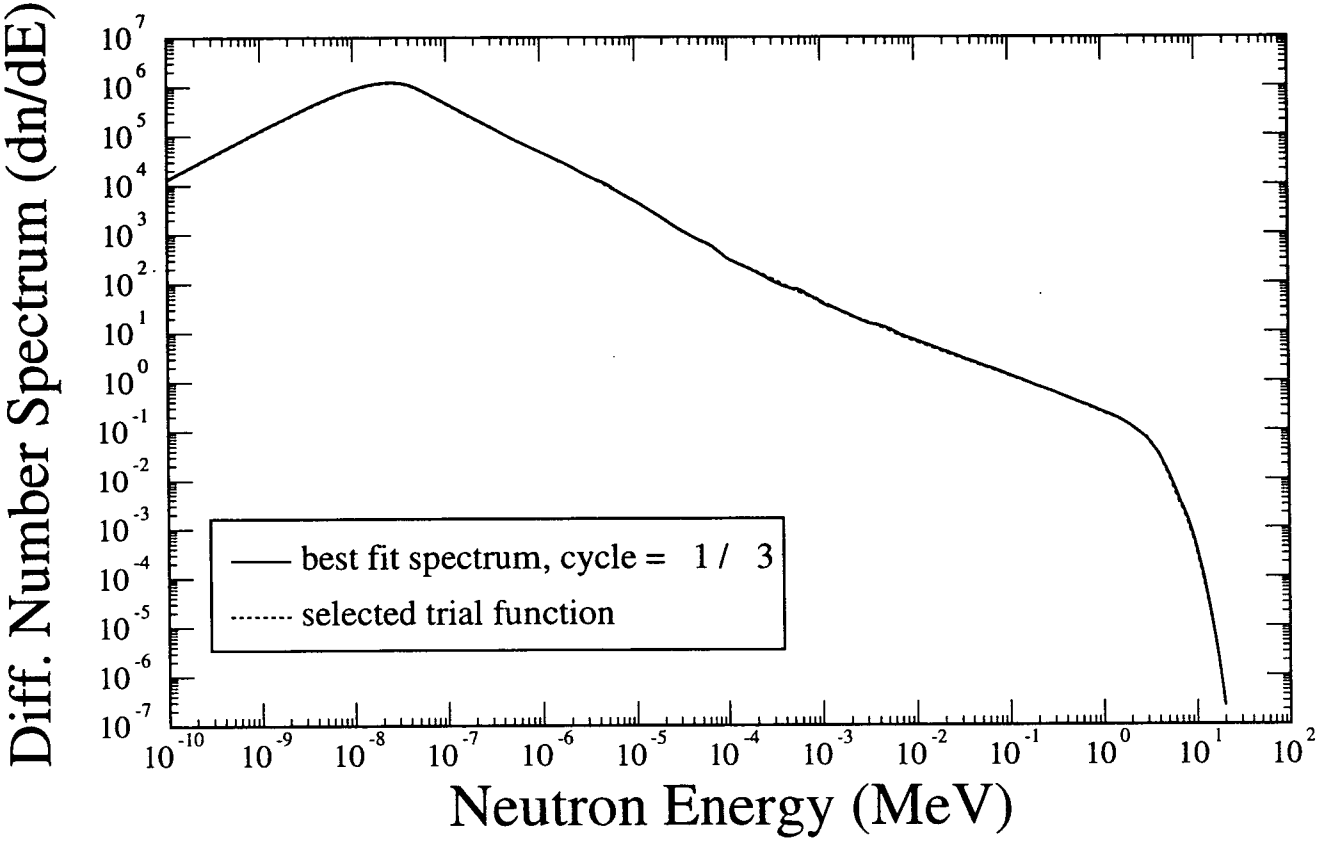

Figure A-3: ACF9 Differential Number Distribution

SNL-SAND-II Run 4:

Environment:	**ACRR New Pb-B_4C Bucket**
File Name:	**TPB13**
Shot Date:	**6/6/90**
Facility Shot Number:	**4681**
Run Conditions:	**160 sec @ 50 kwatt**
Dosimetry Position:	**Dosimetry placed on a cardboard ring and aluminum honeycomb was used to vertically align it with the reactor centerline. The cardboard ring diameter was 2.5 inches.**
	This bucket is composed of 3.8 cm of lead inside 1.27 cm of natural B_4C powder. Top and bottom bucket caps have 2.5 cm of lead inside 1 cm of B_4C. When this bucket is used the experimnetal package can be up to 12.7 cm in diameter.

```
*** snl 6522 endf/b-vi specialized version of sand-ii ***

control parameters:  0 0 4 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
spline knot control file : fission




Job name = tpb13
Library  = snlrml

 1 cases
t acrr "new" pb-b bucket, shot 4681, 6-6-90
t endf/b-vi xsec, full foil set with si
t (nov. 4, 1985), with fitted trial spectrum, lbacrr12.
t
t convert s32p activity to GLUCS-93 with ENDF/B-VI cf-252 spectrum
t   SAND-II activity ratio for conversion is 3.954e-32/4.278-32 = 0.9242636746
t   MANIPULATE xsec ratio for conversion is 70.45055/76.01238 = 0.9268299453
t   the difference is due to numerical roundoff and interpolation of flux
t   we select the SAND-II activity ratio for RML conversion
t
t
 iteration   time integrated
 23 foils
 si1mev
 au197g    cadmium 2.587-3
 au197g
 mn55g     cadmium 2.587-3
 ni58p     cadmium 2.587-3
 al27a     cadmium 2.587-3
 mg24p     cadmium 2.587-3
 fe56p     cadmium 2.587-3
 fe54p     cadmium 2.587-3
 na23g     cadmium 4.705-3
 na23g
 s32p
 zr902     cadmium 2.587-3
```

```
u235f     b4c 0.1481 cadmium 4.705-3
u238f     b4c 0.1481 cadmium 4.705-3
pu239f    b4c 0.1481 cadmium 4.705-3
np237f    b4c 0.1481 cadmium 4.705-3
co59g     cadmium 2.587-3
sc45g     cadmium 2.587-3
tisc46    cadmium 2.587-3
tisc47    cadmium 2.587-3
ti48p     cadmium 2.587-3
zn64p     cadmium 2.587-3
acts 3.736+14
acts 9.208-15 8.715-15 9.575-15 2.046-18 1.114-18
acts 2.363-18 1.004-17 3.237-19 3.144-17
acts 3.263-17 5.845-18 3.569-20
acts 8.218-10 6.691-11 8.472-10 3.608-10
acts 1.885-18 4.414-18 1.485-19 7.183-18 1.601-19
acts 8.777-17
spectrum tabular
45 points
ener    5.00-8  7.20-8  1.00-7  2.00-7
ener    3.00-7  5.00-7  7.20-7  1.00-6  2.00-6
ener    3.00-6  5.00-6  7.20-6  1.00-5  2.00-5
ener    3.00-5  5.00-5  7.20-5  1.00-4  2.00-4
ener    3.00-4  5.00-4  7.20-4  1.00-3  2.00-3
ener    3.00-3  5.00-3  7.20-3  1.00-2  2.00-2
ener    3.00-2  5.00-2  7.20-2  1.00-1  2.00-1
ener    3.00-1  5.00-1  7.20-1  1.00-0  1.50-0
ener    2.00-0  3.00-0  4.00-0  5.00-0  6.00-0
ener    8.00-0
flux    7.80+2  1.10+3  1.60+3  2.60+3
flux    3.40+3  4.70+3  5.80+3  6.50+3  7.80+3
flux    8.20+3  8.30+3  8.20+3  8.00+3  6.90+3
flux    5.60+3  4.20+3  3.20+3  2.50+3  1.50+3
flux    1.18+3  8.70+2  6.80+2  5.30+2  3.35+2
flux    2.50+2  1.75+2  1.40+2  1.12+2  7.00+1
flux    5.30+1  3.75+1  2.95+1  2.35+1  1.45+1
flux    1.03+1  7.00-0  5.20-0  3.80-0  2.60-0
flux    1.80-0  7.30-1  3.40-1  1.72-1  7.00-2
flux    1.40-2
```

```
limit    50
deviation 4.0
discard 3.0
low end e
high end fission
norm 3.000
plot cards
smooth 5
```

interim results after 0 iterations

foil reaction	nominal 5.00 percent activity limits (mev) lower	nominal 5.00 percent activity limits (mev) upper	ratio measured to calculated activities	deviation of measured from calculated activity (percent)
s32 (n,p) p32	2.200E+00	6.800E+00	0.9772	-2.28
ni58 (n,p) co58 Cd	1.700E+00	7.000E+00	1.0135	1.35
na23 (n,g) na24 Cd	1.350E-05	1.900E-01	0.8794	-12.06
na23 (n,g) na24	1.275E-05	1.900E-01	0.9039	-9.61
mg24 (n,p) na24 Cd	6.500E+00	1.170E+01	1.0496	4.96
al27 (n,a) na24 Cd	6.500E+00	1.210E+01	1.0521	5.21
si-28 (n,1mev) x	1.900E-01	4.500E+00	1.0383	3.83
sc45 (n,g) sc46 Cd	3.000E-06	2.300E-01	1.0433	4.33
tinat (n,x) sc46 Cd	3.700E+00	9.200E+00	1.1139	11.39
ti48 (n,p) sc48 Cd	5.900E+00	1.240E+01	1.1483	14.83
tinat (n,x) sc47 Cd	1.500E+00	7.000E+00	0.9328	-6.72
mn55 (n,g) mn56 Cd	4.750E-05	6.900E-03	0.9438	-5.62
fe54 (n,p) mn54 Cd	2.100E+00	7.100E+00	0.9663	-3.37
fe56 (n,p) mn56 Cd	5.400E+00	1.140E+01	1.1115	11.15
co59 (n,g) co60 Cd	7.600E-05	1.500E-04	0.7600	-24.00
zn64 (n,p) cu64 Cd	2.300E+00	7.000E+00	0.9267	-7.33
zr90 (n,2n) zr89 Cd	1.270E+01	1.750E+01	1.1713	17.13
au197(n,g) au198 Cd	4.500E-06	6.600E-03	0.9862	-1.38
au197(n,g) au198	4.500E-06	6.600E-03	0.9310	-6.90

u235 (n,f) fp	B4CCd	2.300E-03	2.900E+00	1.0323	3.23
u238 (n,f) fp	B4CCd	1.400E+00	5.700E+00	1.0838	8.38
np237(n,f) fp	B4CCd	5.250E-01	4.400E+00	0.9910	-0.90
pu239(n,f) fp	B4CCd	4.750E-03	3.300E+00	0.9438	-5.62

---

standard deviation of measured activities (percent) 9.48

average total flux (above 3.00E+00 mev) 3.390E+13

loop 1 iteration 0 9.4812

loop 1 iteration 1 4.8170
loop 1 iteration 2 4.3540
loop 1 iteration 3 4.1248

solution has been achieved.
standard deviation of measured-to-calculated activity ratios is less than 4.00percent./
solution results obtained after 4 iterations

foil reaction	measured activity (dps/nucleus)	calculated activity (dps/nucleus)	nominal 5.00 percent activity limits (mev) lower	nominal 5.00 percent activity limits (mev) upper	ratio measured to calculated activities	deviation of measured from calculated activity (percent)
s32 (n,p) p32	5.845E-18	5.871E-18	2.200E+00	7.000E+00	0.9956	-0.4388
ni58 (n,p) co58 Cd	2.046E-18	2.003E-18	1.700E+00	7.100E+00	1.022	2.164
na23 (n,g) na24 Cd	3.144E-17	3.221E-17	1.150E-05	2.000E-01	0.9762	-2.376
na23 (n,g) na24	3.263E-17	3.252E-17	1.050E-05	2.000E-01	1.003	0.3299
mg24 (n,p) na24 Cd	2.363E-18	2.458E-18	6.500E+00	1.180E+01	0.9615	-3.851
al27 (n,a) na24 Cd	1.114E-18	1.157E-18	6.500E+00	1.220E+01	0.9629	-3.714

si-28 (n,1mev) x		3.736E+14	3.623E+14	1.900E-01	4.500E+00	1.031	3.105
sc45 (n,g) sc46	Cd	4.414E-18	4.243E-18	3.000E-06	2.400E-01	1.040	4.029
tinat (n,x) sc46	Cd	1.485E-19	1.387E-19	3.700E+00	9.300E+00	1.070	7.033
ti48 (n,p) sc48	Cd	1.601E-19	1.526E-19	5.900E+00	1.250E+01	1.049	4.927
tinat (n,x) sc47	Cd	7.183E-18	7.657E-18	1.500E+00	7.100E+00	0.9381	-6.185
mn55 (n,g) mn56	Cd	9.575E-15	9.607E-15	4.000E-05	7.600E-03	0.9967	-0.3325
fe54 (n,p) mn54	Cd	3.237E-19	3.317E-19	2.100E+00	7.200E+00	0.9758	-2.419
fe56 (n,p) mn56	Cd	1.004E-17	9.849E-18	5.400E+00	1.150E+01	1.019	1.935
co59 (n,g) co60	Cd	1.885E-18	1.891E-18	4.750E-05	1.600E-04	0.9968	-0.3209
zn64 (n,p) cu64	Cd	8.777E-17	9.326E-17	2.300E+00	7.200E+00	0.9412	-5.883
zr90 (n,2n) zr89	Cd	3.569E-20	3.575E-20	1.270E+01	1.750E+01	0.9984	-0.1635
au197(n,g) au198	Cd	9.208E-15	8.971E-15	4.500E-06	8.000E-03	1.026	2.640
au197(n,g) au198		8.715E-15	8.994E-15	4.500E-06	8.000E-03	0.9690	-3.097
u235 (n,f) fp	B4CCd	8.218E-10	8.018E-10	2.550E-03	2.900E+00	1.025	2.491
u238 (n,f) fp	B4CCd	6.691E-11	6.207E-11	1.400E+00	5.900E+00	1.078	7.793
np237(n,f) fp	B4CCd	3.608E-10	3.660E-10	5.250E-01	4.500E+00	0.9857	-1.432
pu239(n,f) fp	B4CCd	8.472E-10	9.035E-10	5.500E-03	3.300E+00	0.9377	-6.234
							------

standard deviation of measured activities (percent) 3.966

---

response analysis - loop = 1 iteration = 4

response function	dose
fluence (n/cm**2)	0.6832604E+15
kerma (rad-tissue)	955125.2
cp dose to elem-57 (rad-tissue)	1056944.
dose eqv. (rem)	0.1158082E+08
dose to elem-57 from h-1(n,g)h-2 (rad-tissue)	198960.2
ansi and ncrp dose (rem)	0.1194448E+08

---

spectrum characterization

total fluence (n/cm**2)	6.8326004E+14	
fluence > 10 kev	5.7458140E+14	(0.8409410)
fluence > 3 Mev	3.3100392E+13	(4.8444796E-02)
fluence < 1 eV	1.5495437E+11	(2.2678681E-04)
avg. energy (mev)	0.7330868	
HP-ASTM E722-85	0.5689850	
(ASTM Si damage function)		
HP-ASTM E722-93	0.5297971	
(ENDF-6 Si damage function)		
HP-10kev E722-85	0.6766051	
(ASTM Si damage function)		
HP-10kev E722-93	0.6300051	
(ENDF-6 Si damage function)		
SP	17.35875	
(F[>10 kev]/F[>3 MeV)])		
SP	20.64205	
(F[tot]/F[>3 MeV)])		
sulfer cross section (mb)	315.2602	
(spectrum averaged, > 3 mev)		
nickel cross section (mb)	534.4255	
(spectrum averaged, > 3 mev)		
sulfer cross section (mb)	15.27271	
(spectrum averaged, > total)		
nickel cross section (mb)	25.89014	
(spectrum averaged, total)		
gaas 1 mev fluence	4.0157240E+14	(0.5877299)
(ref-sig[gaas] = 70 mev-mb)		
silicon 1 mev fluence	3.6234814E+14	(0.5303224)
(ref-sig[si] = 95 mev-mb)		
old ASTM Si 1 mev flu.	3.8876470E+14	(0.5689850)
(ref-sig[si] = 95 mev-mb)		
S32 Act. -dps/gm meas-ENDF	7127252.	(1.0431243E-08)
S32 Act. - Bq/atom meas.	5.8449997E-18	(8.5545756E-33)
S32 Act. - Bq/atom calc.	5.8707622E-18	(8.5922811E-33)
252-Cf Eq. Flu. S32 Meas.-n/cm2	1.4790445E+14	
252-Cf Eq. Flu. S32 Calc.-n/cm2	1.4855636E+14	

Ni58 Act. - Bq/atom meas.	2.0460000E-18	(2.9944675E-33)
Ni58 Act. - Bq/atom calc.	2.0026680E-18	(2.9310480E-33)

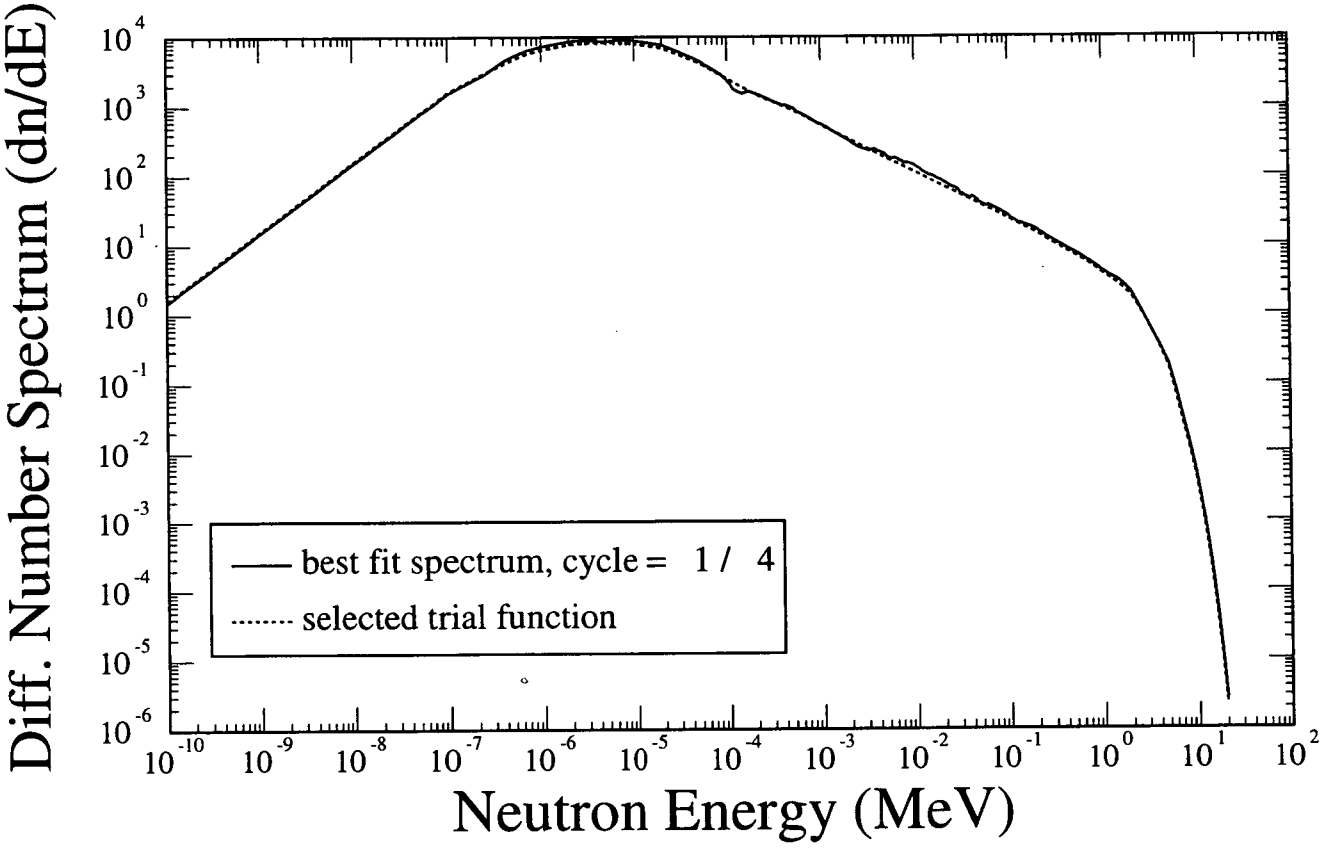

Figure A-4: TPB13 Differential Number Distribution

SNL-SAND-II Run 5:

Environment:	**NIST ^{252}Cf Reference Benchmark Source**
File Name:	**CF252-activity**
Shot Date:	**---**
Facility Shot Number:	**Representative of a NIST Irradiation. The ^{252}Cf spectrum is taken from the ENDF/B-VI library and appears in Tape 200, MAT=9861, MT=18,MF=5.**
Run Conditions:	**This represents a SNL-SAND-II activity run used to characterize the response of the sensors in the SNLRML library to a ^{252}Cf neutron field.**
Dosimetry Position:	**Free-in-air irradiation corresponding to an irradiation at the NIST XCF-5-N1 benchmark field.**

```
*** snl 6522 endf/b-vi specialized version of sand-ii ***

control parameters:  0 0 4 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
spline knot control file : fission



Job name = cf252-activity
Library  = snlrml

 1 cases
t snlrml activity list
t
t
 activity   time integrated
76 foils
b10he4
li6he4
f192
na23g
mg24p
al27p
al27a
si1mev
p31p
s32p
sc45g
ti46p
ti47p
ti47np
tisc46
ti48p
ti48np
tisc47
mn55g
mn552
fe54p
```

fe56p
fe58g
fedpa
co59p
co59g
co59a
co592
ni58p
ni582
ni60p
cu63g
cu632
cu63a
cu652
zn64p
zr902
gaas1mev
nb93g
nb932
nb93n
mo98g
rh103n
ag109g
in115g
in115n
i1272
au197p
au197g
au1972
au1973
th232g
th2322
th232f
u235f
u238f
np237f
pu239f
am241f
rmleu

```
rmldu
rmlpu
s3mev
na23gj
fe58gj
fe58gjef
sc45gj
mn55g6
u234f
u236f
pu240f
pu241f
pu242f
pu238f
fe54a
s32pvd
spectrum  low

    ****  SNL combined energy/flux input spectrum format invoked ****
                        Energy-Flux Listing

 122 points
  0.000000E+00  0.000000E+00    0.100000E-10  0.203300E-05    0.200000E-10  0.287500E-05    0.500000E-10  0.454600E-05
  0.100000E-09  0.643000E-05    0.200000E-09  0.909300E-05    0.500000E-09  0.143800E-04    0.100000E-08  0.203300E-04
  0.200000E-08  0.287500E-04    0.500000E-08  0.454600E-04    0.100000E-07  0.643000E-04    0.200000E-07  0.909300E-04
  0.500000E-07  0.143800E-03    0.100000E-06  0.203300E-03    0.200000E-06  0.287500E-03    0.500000E-06  0.454600E-03
  0.100000E-05  0.643000E-03    0.200000E-05  0.909300E-03    0.500000E-05  0.143800E-02    0.100000E-04  0.203300E-02
  0.200000E-04  0.287500E-02    0.500000E-04  0.454600E-02    0.100000E-03  0.642900E-02    0.200000E-03  0.909200E-02
  0.500000E-03  0.143700E-01    0.100000E-02  0.203200E-01    0.200000E-02  0.287100E-01    0.500000E-02  0.453000E-01
  0.100000E-01  0.638500E-01    0.250000E-01  0.998900E-01    0.300000E-01  0.109000E+00    0.350000E-01  0.117400E+00
  0.450000E-01  0.132200E+00    0.550000E-01  0.145200E+00    0.700000E-01  0.162200E+00    0.850000E-01  0.176900E+00
  0.100000E+00  0.190000E+00    0.130000E+00  0.212300E+00    0.160000E+00  0.230800E+00    0.200000E+00  0.251200E+00
  0.250000E+00  0.271600E+00    0.300000E+00  0.287700E+00    0.370000E+00  0.304900E+00    0.460000E+00  0.320100E+00
  0.500000E+00  0.324800E+00    0.600000E+00  0.332900E+00    0.700000E+00  0.336300E+00    0.850000E+00  0.335200E+00
  0.100000E+01  0.328900E+00    0.120000E+01  0.315200E+00    0.150000E+01  0.287500E+00    0.200000E+01  0.235200E+00
  0.240000E+01  0.195000E+00    0.270000E+01  0.167700E+00    0.300000E+01  0.143100E+00    0.330000E+01  0.121300E+00
  0.350000E+01  0.108200E+00    0.370000E+01  0.963600E-01    0.390000E+01  0.855900E-01    0.410000E+01  0.758800E-01
```

0.430000E+01	0.671600E-01	0.450000E+01	0.593700E-01	0.470000E+01	0.524200E-01	0.490000E+01	0.462500E-01
0.510000E+01	0.407800E-01	0.530000E+01	0.359200E-01	0.550000E+01	0.316300E-01	0.570000E+01	0.278200E-01
0.590000E+01	0.244600E-01	0.610000E+01	0.214900E-01	0.630000E+01	0.188700E-01	0.650000E+01	0.165500E-01
0.670000E+01	0.145100E-01	0.690000E+01	0.127200E-01	0.710000E+01	0.111400E-01	0.730000E+01	0.975500E-02
0.750000E+01	0.854000E-02	0.770000E+01	0.747500E-02	0.790000E+01	0.654100E-02	0.810000E+01	0.572500E-02
0.830000E+01	0.501100E-02	0.850000E+01	0.438500E-02	0.870000E+01	0.383800E-02	0.890000E+01	0.336000E-02
0.910000E+01	0.294000E-02	0.930000E+01	0.257300E-02	0.950000E+01	0.225200E-02	0.970000E+01	0.197000E-02
0.990000E+01	0.172300E-02	0.101000E+02	0.150600E-02	0.103000E+02	0.131700E-02	0.105000E+02	0.115100E-02
0.107000E+02	0.100700E-02	0.109000E+02	0.880200E-03	0.111000E+02	0.769700E-03	0.113000E+02	0.672900E-03
0.115000E+02	0.588300E-03	0.117000E+02	0.514200E-03	0.119000E+02	0.449400E-03	0.121000E+02	0.392700E-03
0.123000E+02	0.343000E-03	0.125000E+02	0.299600E-03	0.127000E+02	0.261700E-03	0.129000E+02	0.228400E-03
0.131000E+02	0.199400E-03	0.132000E+02	0.186200E-03	0.134000E+02	0.162500E-03	0.135000E+02	0.151700E-03
0.137000E+02	0.132300E-03	0.139000E+02	0.115400E-03	0.141000E+02	0.100700E-03	0.142000E+02	0.939900E-04
0.144000E+02	0.819500E-04	0.146000E+02	0.714500E-04	0.153000E+02	0.442000E-04	0.160000E+02	0.273300E-04
0.167000E+02	0.168800E-04	0.174000E+02	0.104200E-04	0.181000E+02	0.642200E-05	0.188000E+02	0.395000E-05
0.195000E+02	0.242700E-05	0.200000E+02	0.171300E-05				

low end e
high end fission
norm 0.010
plot cards

activity calculation results

(normalized to 1.00E-02 mev)

foil reaction	calculated activity (dps/nucleus)	nominal 5.00 percent activity limits (mev), lower	nominal 5.00 percent activity limits (mev), upper	actual activity outside limits (percent) lower	actual activity outside limits (percent) upper
s32 (n,p) p32	3.954E-32	2.400E+00	7.800E+00	5.708	4.977
ni58 (n,p) co58	1.306E-32	2.100E+00	7.900E+00	4.991	5.165
b10 (n,he4) x	5.379E-25	7.200E-02	5.300E+00	5.031	4.848
li-6 (n,he4) x	4.730E-25	1.700E-01	6.100E+00	4.819	5.009
f19 (n,2n) f18	1.806E-33	1.200E+01	1.760E+01	5.091	5.066

na23 (n,g) na24	3.502E-33	5.250E-02	4.700E+00	4.783	4.946
mg24 (n,p) na24	2.784E-32	6.600E+00	1.210E+01	5.982	5.020
al27 (n,p) mg27	5.712E-30	3.500E+00	9.800E+00	5.319	5.040
al27 (n,a) na24	1.336E-32	6.600E+00	1.250E+01	5.197	4.935
si-28 (n,1mev) x	1.058E+00	4.500E-01	6.100E+00	4.885	5.047
p31 (n,p) si31	2.254E-30	2.300E+00	7.700E+00	5.721	4.960
sc45 (n,g) sc46	5.097E-34	3.200E-02	2.900E+00	4.873	4.856
ti46 (n,p) sc46	1.182E-33	3.800E+00	9.900E+00	4.768	5.151
ti47 (n,p) sc47	4.650E-32	1.800E+00	8.200E+00	5.003	5.077
ti47 (n,np) sc46	2.203E-36	1.170E+01	1.800E+01	5.225	4.974
tinat (n,x) sc46	1.184E-33	3.800E+00	1.000E+01	4.762	4.956
ti48 (n,p) sc48	1.708E-33	6.000E+00	1.290E+01	4.597	5.001
ti48 (n,np) sc47	9.657E-36	1.240E+01	1.860E+01	5.536	4.862
tinat (n,x) sc47	4.660E-32	1.800E+00	8.300E+00	4.993	4.982
mn55 (n,g) mn56	2.108E-31	2.300E-02	3.900E+00	5.073	5.007
mn55 (n,2n) mn54	1.235E-35	1.110E+01	1.630E+01	5.123	5.118
fe54 (n,p) mn54	2.266E-33	2.400E+00	8.000E+00	5.294	4.922
fe56 (n,p) mn56	1.024E-31	5.600E+00	1.200E+01	5.499	4.859
fe58 (n,g) fe59	4.465E-34	5.750E-02	3.700E+00	4.991	4.823
fe (n,x) dpa	8.983E-22	6.600E-01	6.800E+00	4.976	4.846
co59 (n,p) fe59	3.054E-34	3.600E+00	1.030E+01	5.336	5.128
co59 (n,g) co60	1.995E-35	6.000E-02	3.500E+00	4.956	5.074
co59 (n,a) mn56	1.616E-32	5.900E+00	1.270E+01	5.351	4.894
co59 (n,2n) co58	4.776E-35	1.130E+01	1.650E+01	4.551	5.091
ni58 (n,2n) ni59	4.951E-35	1.310E+01	1.830E+01	4.843	4.822
ni60 (n,p) co60	1.040E-35	4.800E+00	1.140E+01	4.605	4.992
cu63 (n,g) cu64	1.579E-31	6.300E-02	4.100E+00	4.941	4.950
cu63 (n,2n) cu64	2.474E-31	1.190E+01	1.730E+01	4.412	5.169
cu63 (n,a) co60	2.830E-36	4.700E+00	1.160E+01	4.996	4.901
cu65 (n,2n) cu64	1.026E-32	1.090E+01	1.620E+01	5.213	5.032
zn64 (n,p) cu64	6.386E-31	2.500E+00	8.000E+00	5.154	5.019
zr90 (n,2n) zr89	5.393E-34	1.280E+01	1.780E+01	5.765	4.847
gaas (n,1mev) x	5.192E-21	4.000E-01	6.200E+00	4.794	4.889
nb93 (n,g) nb94	4.869E-29	4.000E-02	2.700E+00	5.005	4.936
nb93 (n,2n)nb92m	5.779E-34	1.000E+01	1.490E+01	5.357	4.925
nb93 (n,n) nb93m	1.942E-34	1.000E+00	6.100E+00	5.245	5.120
mo98 (n,g) mo99	7.572E-32	1.275E-01	3.200E+00	4.946	4.856
rh103(n,n)rh103m	1.470E-28	7.600E-01	6.100E+00	5.026	5.008
ag109(n,g)ag110m	1.785E-34	4.750E-02	3.000E+00	5.016	5.245

in115(n,g)in116m	3.276E-29	1.000E-01	3.000E+00	4.958	4.724
in115(n,n)in115m	8.141E-30	1.200E+00	6.200E+00	5.268	5.015
i127 (n,2n) i126	1.451E-33	9.800E+00	1.510E+01	5.223	4.905
au197(n,p) pt197	2.474E-35	6.900E+00	1.670E+01	4.862	4.931
au197(n,g) au198	2.213E-31	5.250E-02	2.800E+00	5.030	4.961
au197(n,2n) au19	1.132E-24	8.900E+00	1.410E+01	5.384	5.155
au197(n,3n) au19	2.184E-27	1.630E+01	1.970E+01	4.975	5.700
th232(n,g) th233	4.652E-29	9.200E-02	2.900E+00	5.055	5.167
th232(n,2n) th23	5.173E-24	7.100E+00	1.180E+01	4.719	5.137
th232(n,f) fp	7.846E-26	1.500E+00	7.600E+00	4.522	5.186
u235 (n,f) fp	1.219E-24	2.100E-01	5.700E+00	4.946	4.995
u238 (n,f) fp	3.151E-25	1.500E+00	7.200E+00	5.039	4.925
np237(n,f) fp	1.335E-24	7.200E-01	6.100E+00	5.378	5.037
pu239(n,f) fp	1.790E-24	2.800E-01	5.600E+00	4.849	5.060
am241(n,f) fp	1.427E-24	9.200E-01	6.200E+00	4.832	4.930
u235 (n,f) rml	1.165E-24	2.200E-01	5.700E+00	5.085	5.109
u238 (n,f) rml	3.170E-25	1.500E+00	7.200E+00	5.351	4.903
pu239(n,f) rml	1.737E-24	3.000E-01	5.700E+00	4.906	4.903
s32 (n,p) p32	7.028E-26	2.400E+00	7.800E+00	5.708	4.977
na23 (n,g) jendl	2.885E-33	4.500E-02	5.200E+00	5.003	5.124
fe58 (n,g) jendl	3.258E-34	3.400E-02	3.000E+00	4.986	4.877
fe58 (n,g) jef	3.590E-34	6.600E-02	4.000E+00	4.971	5.130
sc45 (n,g) jendl	6.613E-34	4.500E-02	2.800E+00	5.035	5.100
mn55 (n,g) mn56	2.126E-31	2.700E-02	3.800E+00	5.039	5.190
u234 (n,f) fp	1.237E-24	6.600E-01	6.100E+00	5.370	4.955
u236 (n,f) fp	5.950E-25	1.000E+00	6.800E+00	3.834	5.112
pu240(n,f) fp	1.368E-24	6.900E-01	6.000E+00	4.754	5.128
pu241(n,f) fp	1.598E-24	2.100E-01	5.500E+00	5.124	5.004
pu242(n,f) fp	1.136E-24	7.600E-01	6.100E+00	4.630	5.104
pu238(n,f) fp	1.988E-24	4.500E-01	5.800E+00	4.995	5.060
fe54 (n,a) cr51	3.427E-34	5.000E+00	1.170E+01	4.663	4.976
s32 (n,p) p32	4.278E-32	2.300E+00	7.800E+00	4.443	5.117

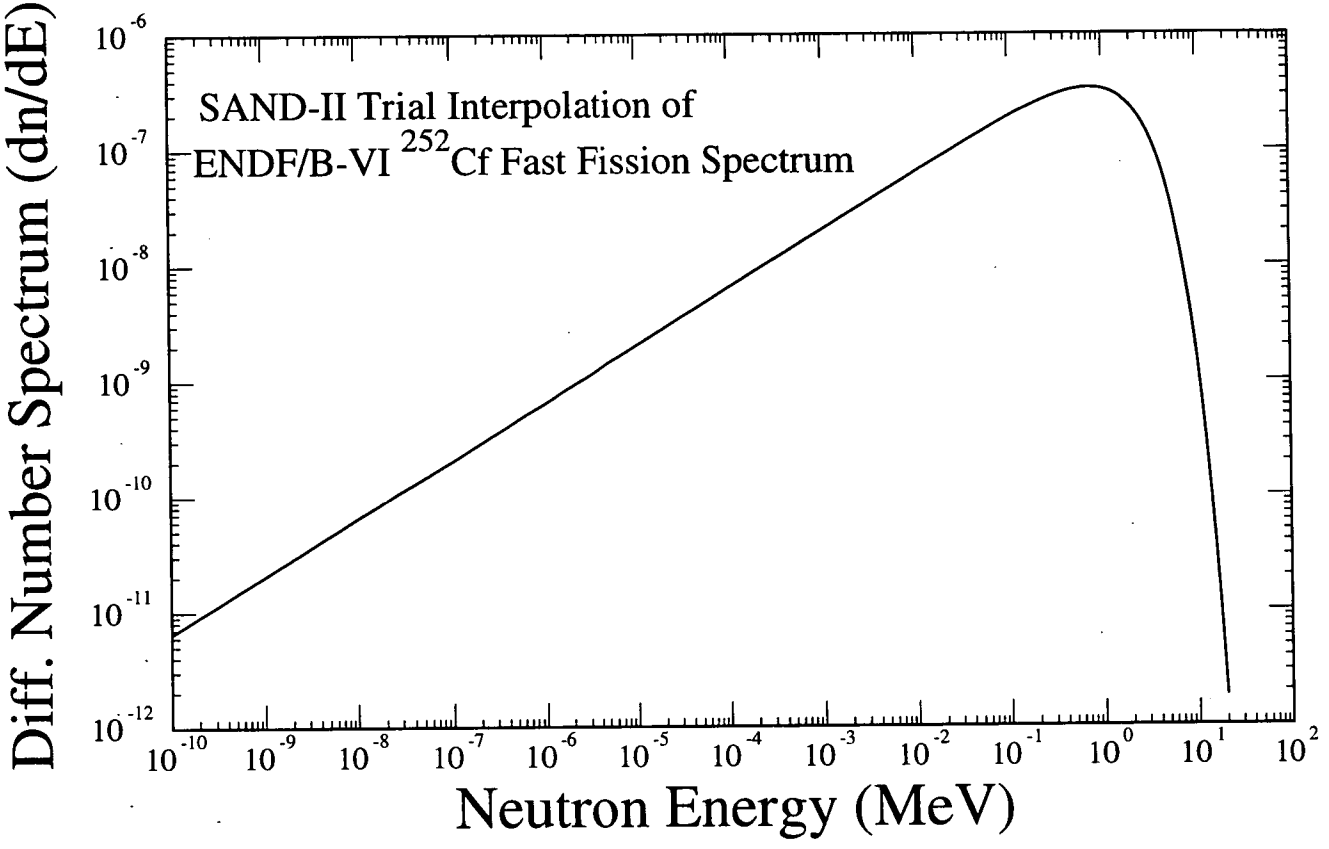

Figure A-5: CF252VI Differential Number Distribution

APPENDIX B

ACE/gr Sample Plots

SNL-SAND-II Sample Plot 1:

Environment:	**SPR-III Central Cavity**
File Name:	**SPR3CC**
Shot Date:	**12/1/92**
Facility Shot Number:	**8827**
Run Conditions:	**250 sec @ 1 kwatt**
Dosimetry Position:	**Position in central cavity with RCC cardboard fixture and aluminum honeycomb to attain vertical centerline position. Used cart for experiment insertion.**

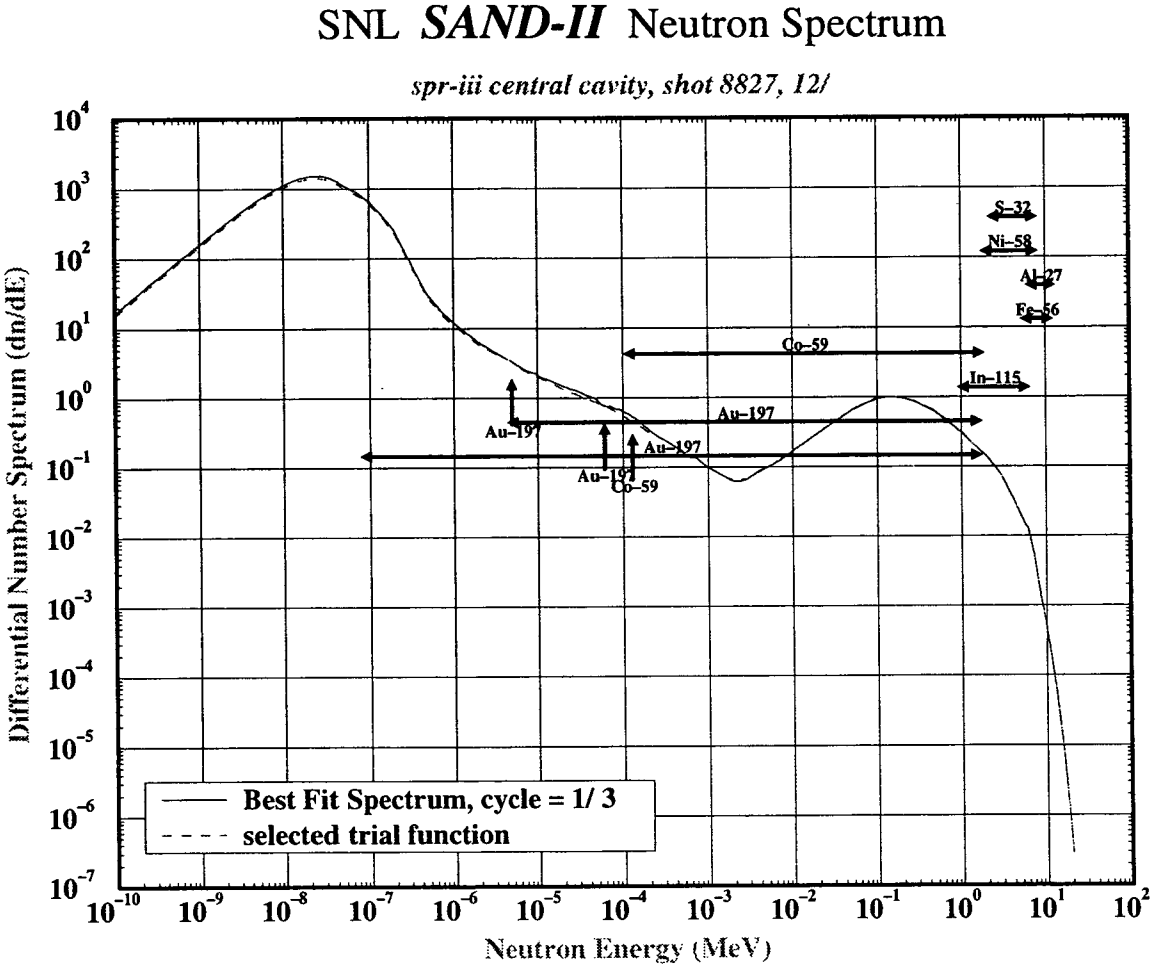

Figure B-1: ACE/gr SPR3CC Spectrum Plot

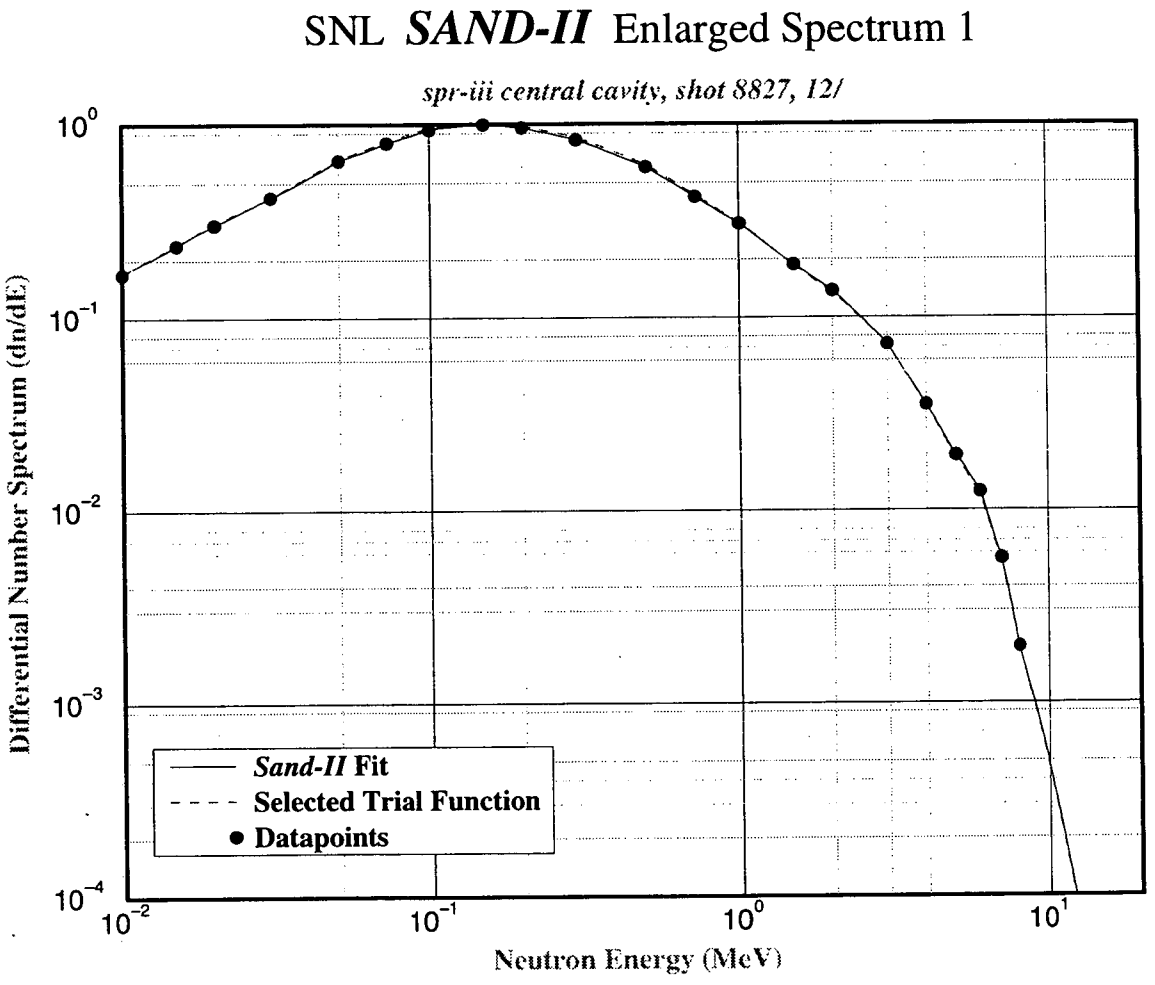

Figure B-2: ACE/gr SPR3CC Enlarged Spectrum Plot

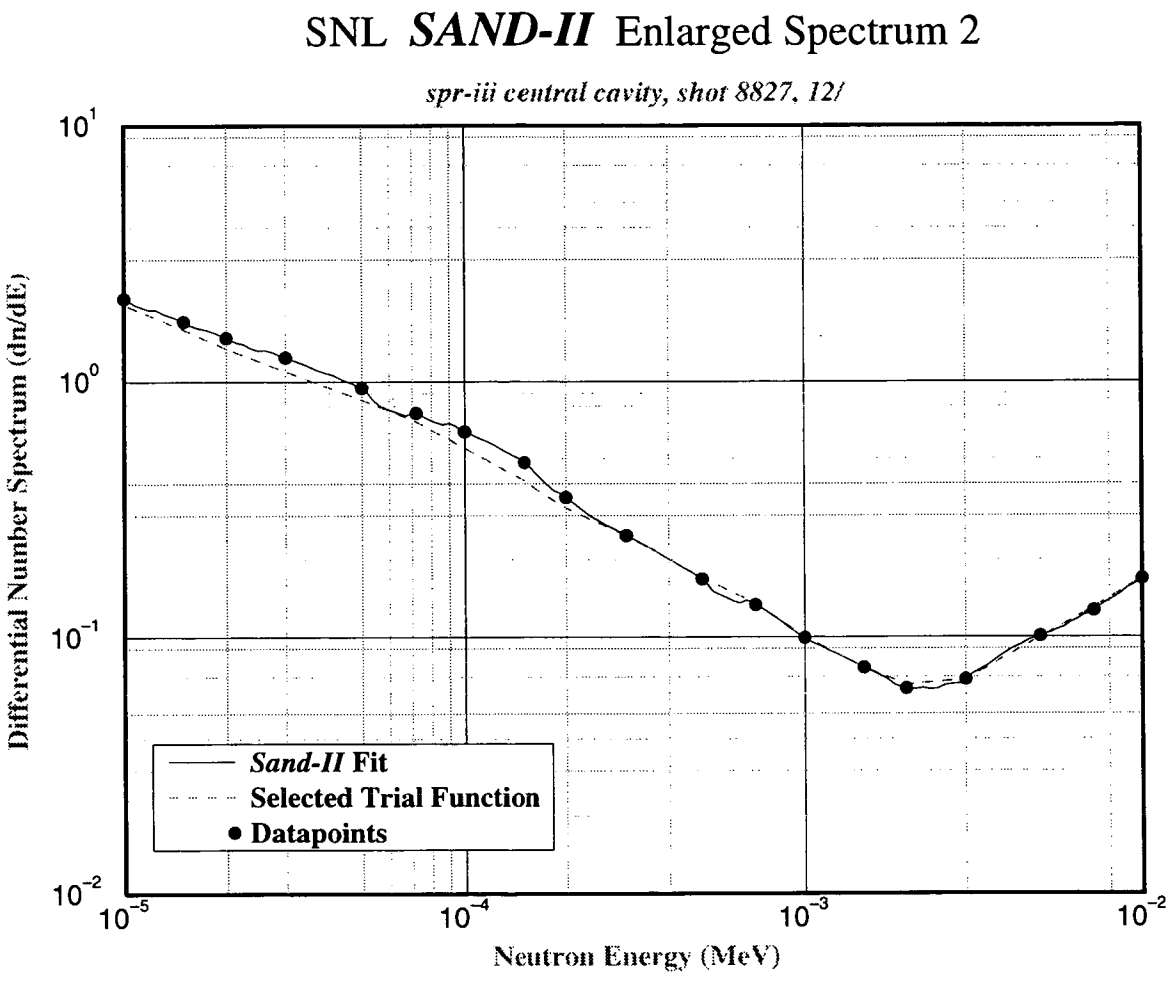

Figure B-3: ACE/gr SPR3CC Enlarged Spectrum Plot

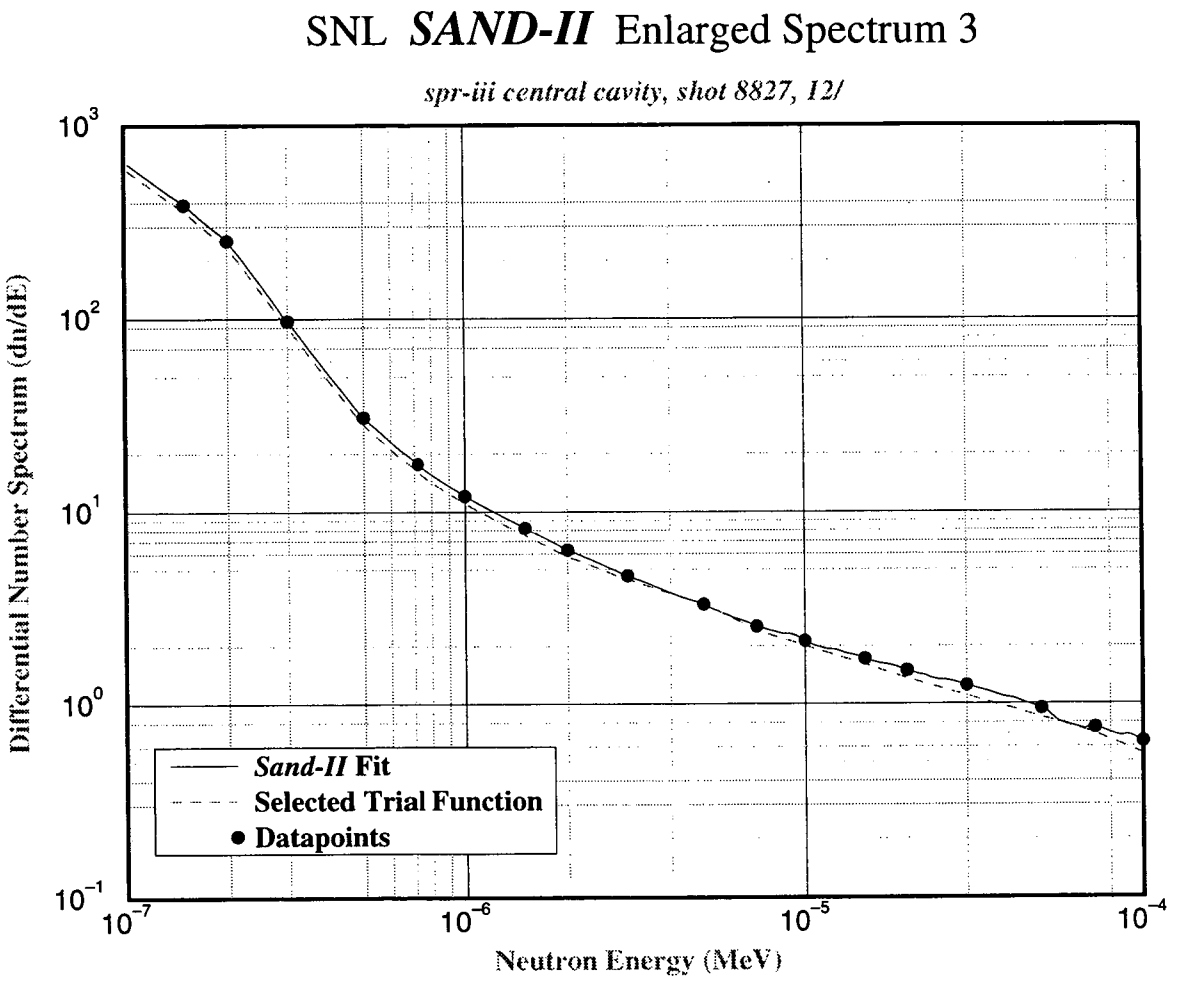

Figure B-4: ACE/gr SPR3CC Enlarged Spectrum Plot

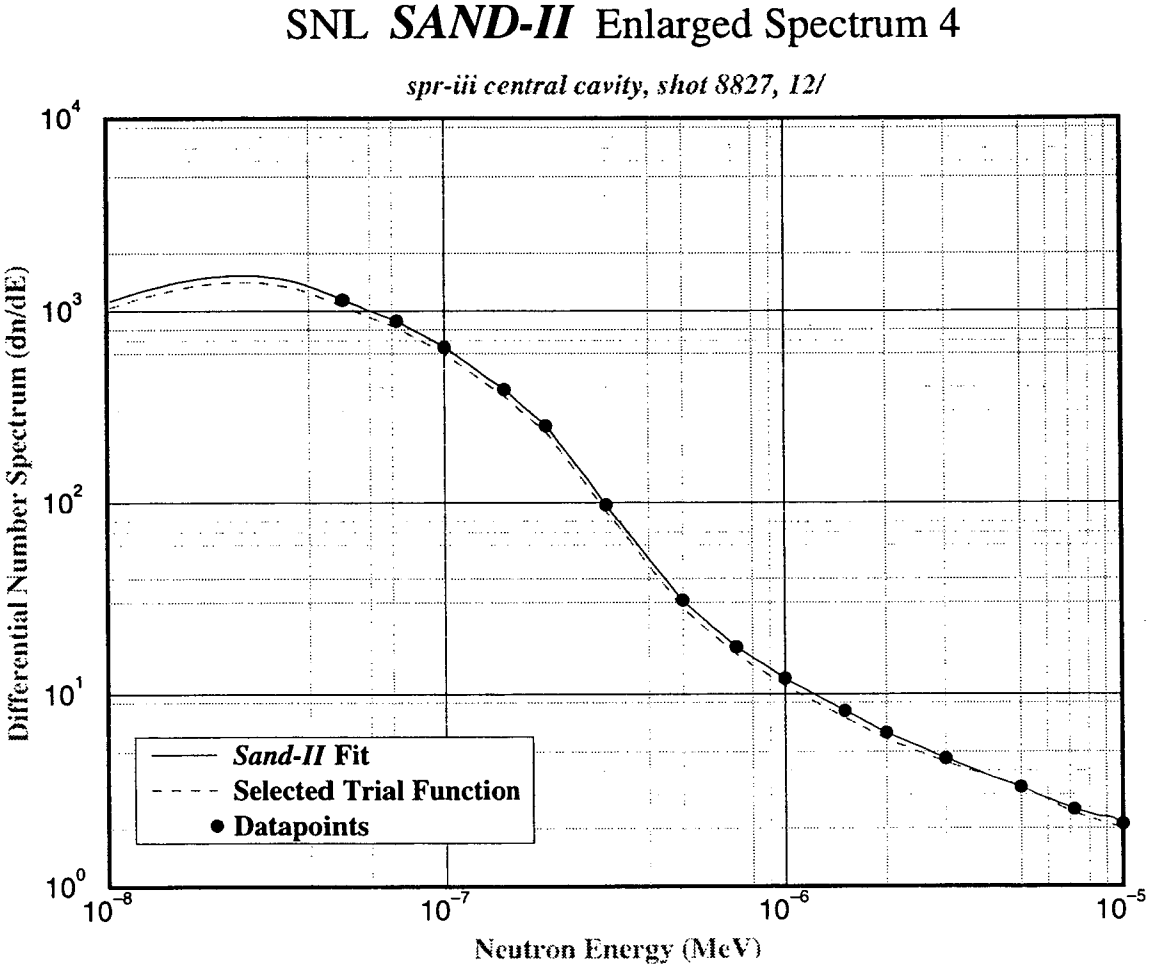

Figure B-5: ACE/gr SPR3CC Enlarged Spectrum Plot

SNL-SAND-II Sample Plot 2:

Environment:	**SPR-III 17" Leakage**
File Name:	**SCR4**
Shot Date:	**10/5/88**
Facility Shot Number:	**6338**
Run Conditions:	**1000 sec @ 10 kwatt**
Dosimetry Position:	**Dosimetry on curved aluminum plate located at reactor centerline. The azimuthal position is fixed to along the line through the copper control rod.**

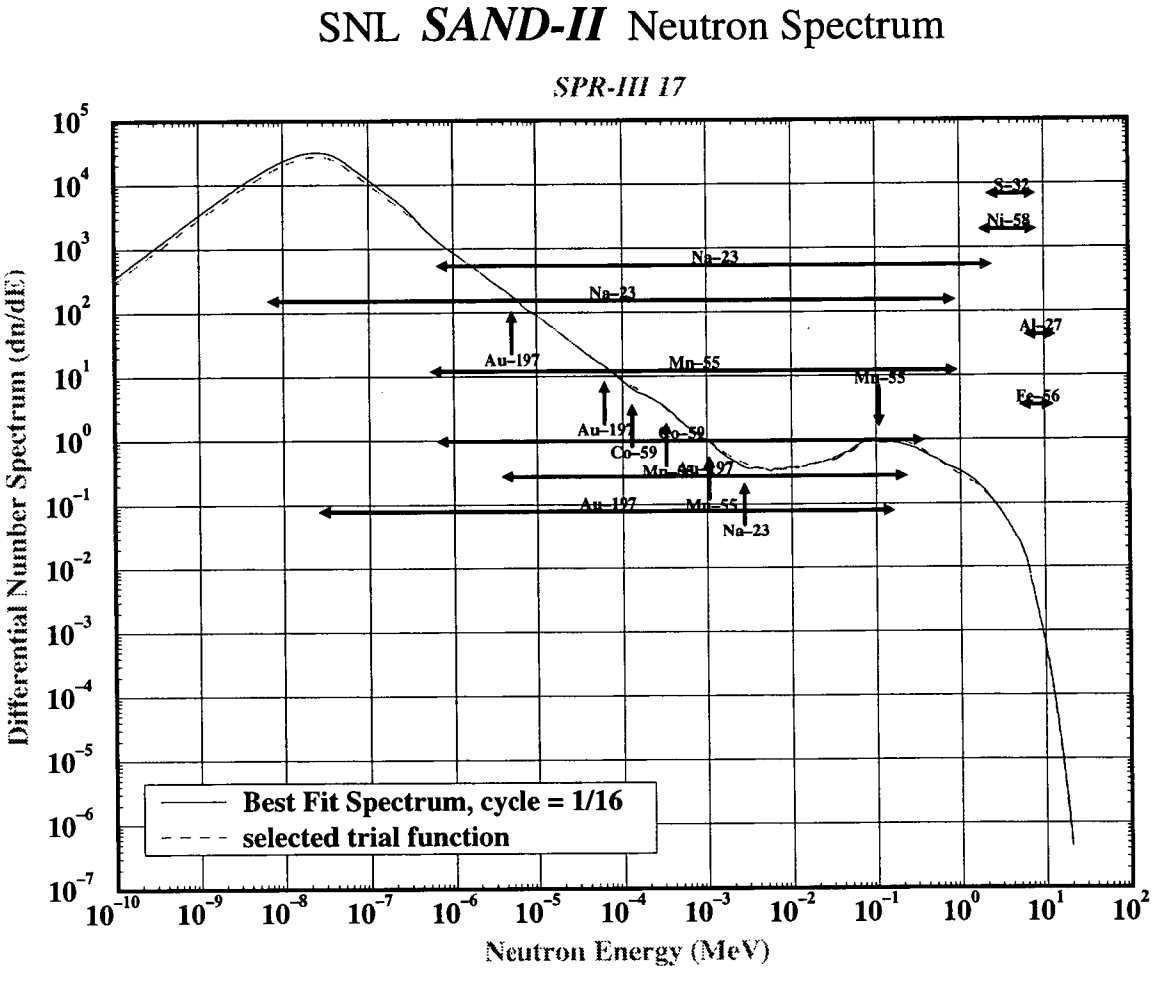

Figure B-6: ACE/gr SCR4 Spectrum Plot

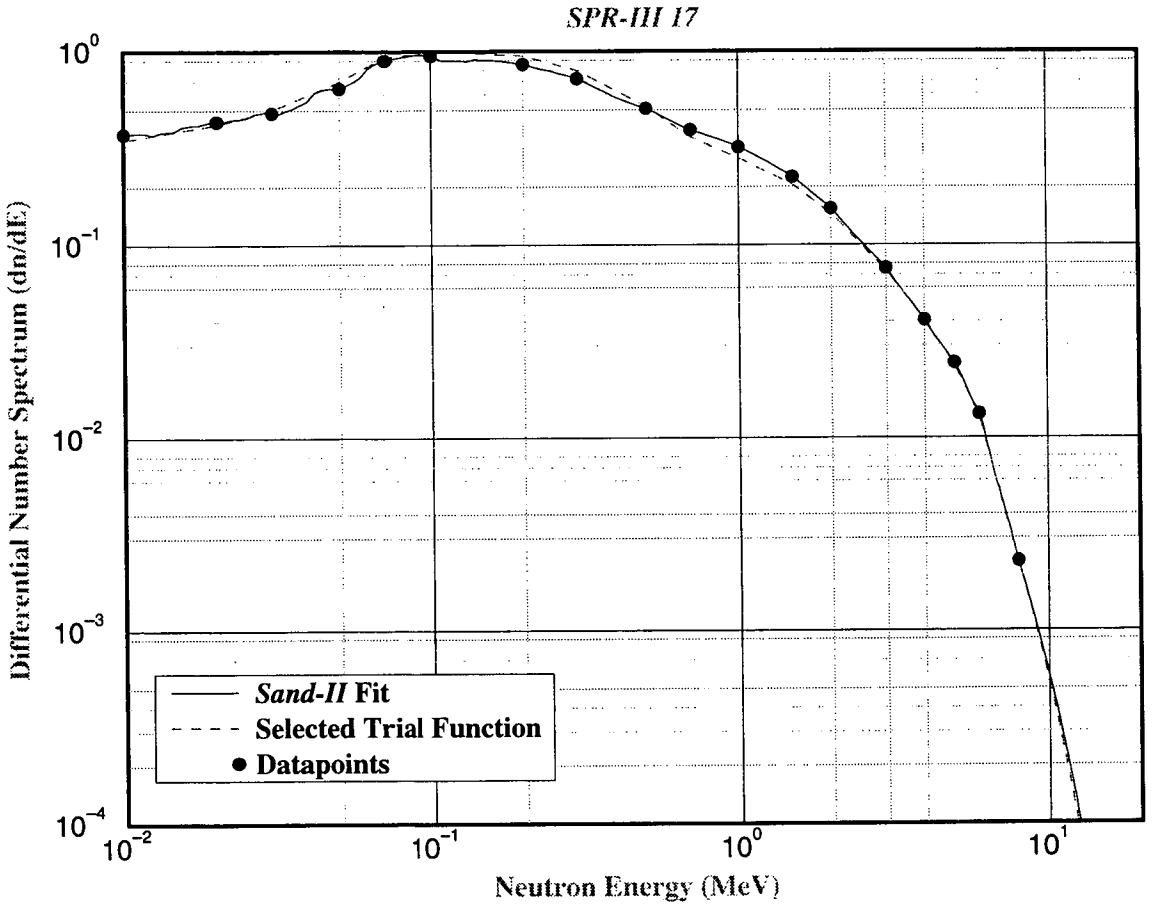

Figure B-7: ACE/gr SCR4 Enlarged Spectrum Plot

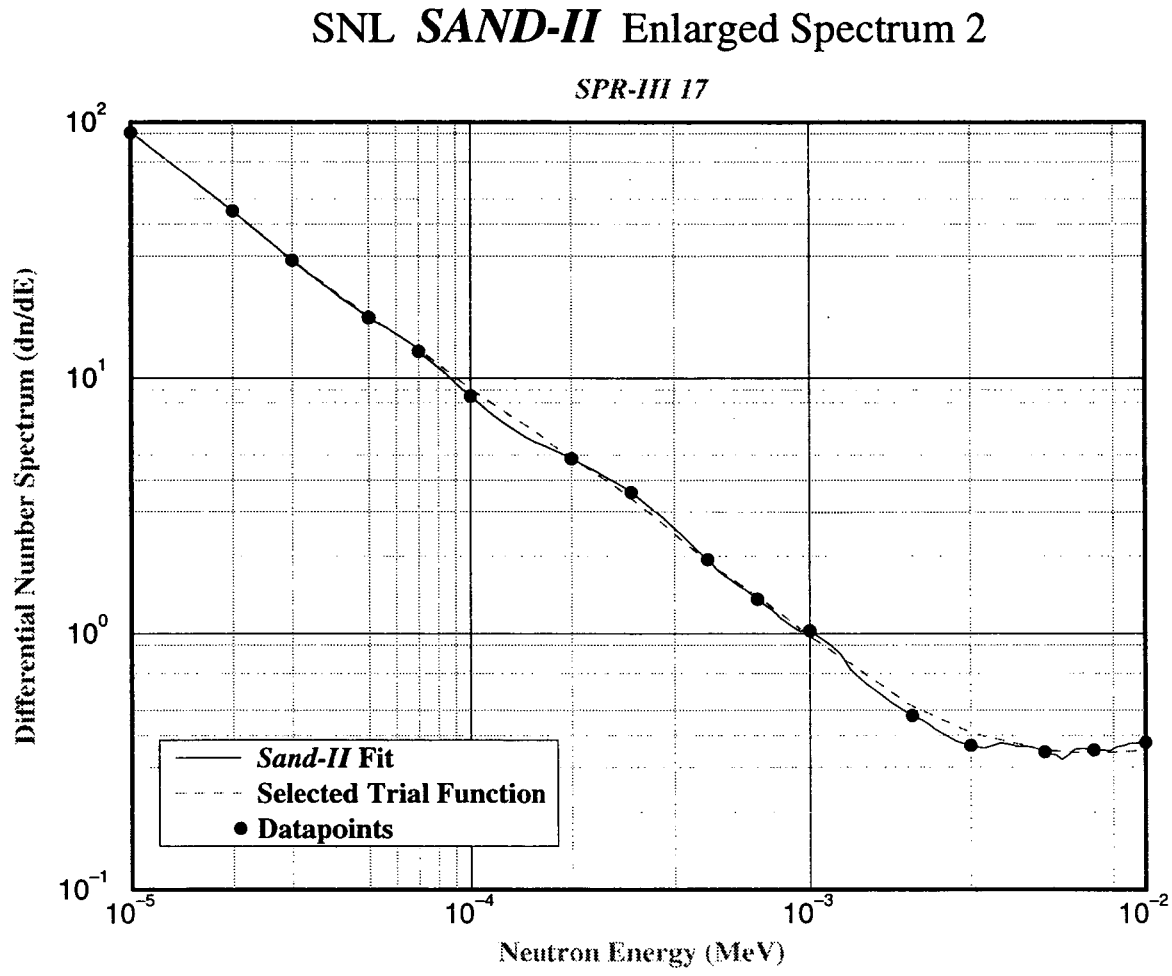

Figure B-8: ACE/gr SCR4 Enlarged Spectrum Plot

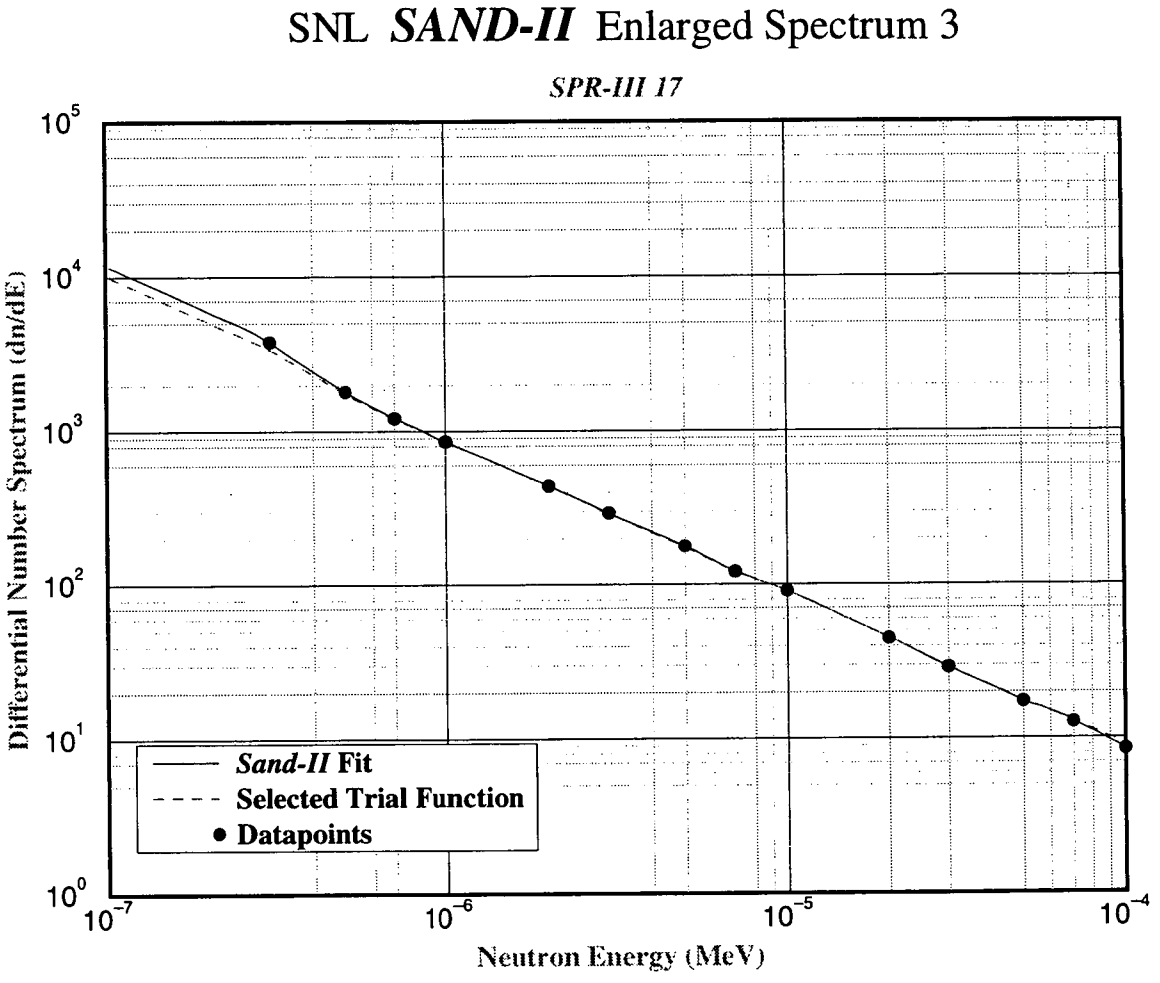

Figure B-9: ACE/gr SCR4 Enlarged Spectrum Plot

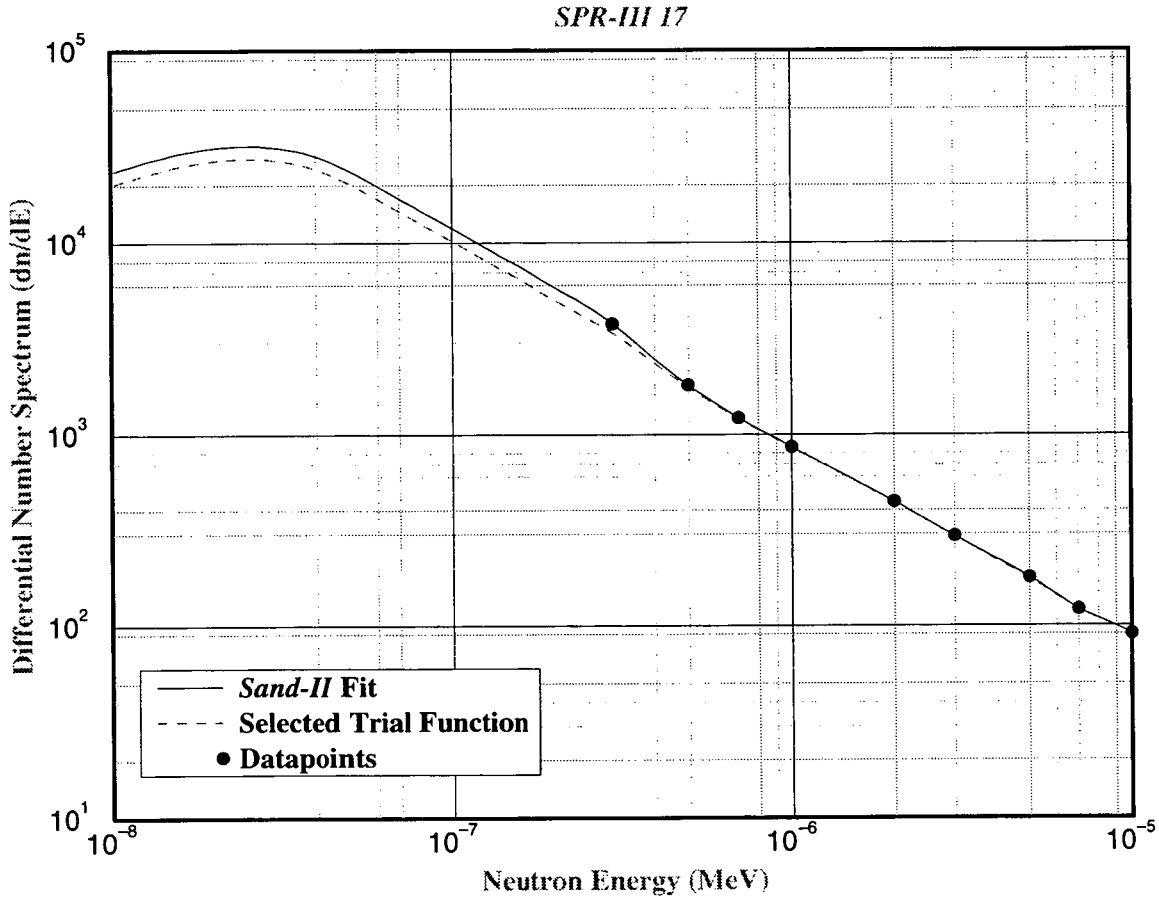

Figure B-10: ACE/gr SCR4 Enlarged Spectrum Plot

SNL-SAND-II Sample Plot 3:

Environment:	**ACRR Central Cavity**
File Name:	**ACF9**
Shot Date:	**7/14/92**
Facility Shot Number:	**5407**
Run Conditions:	**100sec @ 150 kwatt**
Dosimetry Position:	**Dosimetry fixed on cardboard fixture with in small aluminum frame. Aluminum honeycomb was used to place the dosimetry along the reactor centerline. This run was performed in two parts, 65 and 35 seconds respectively.**

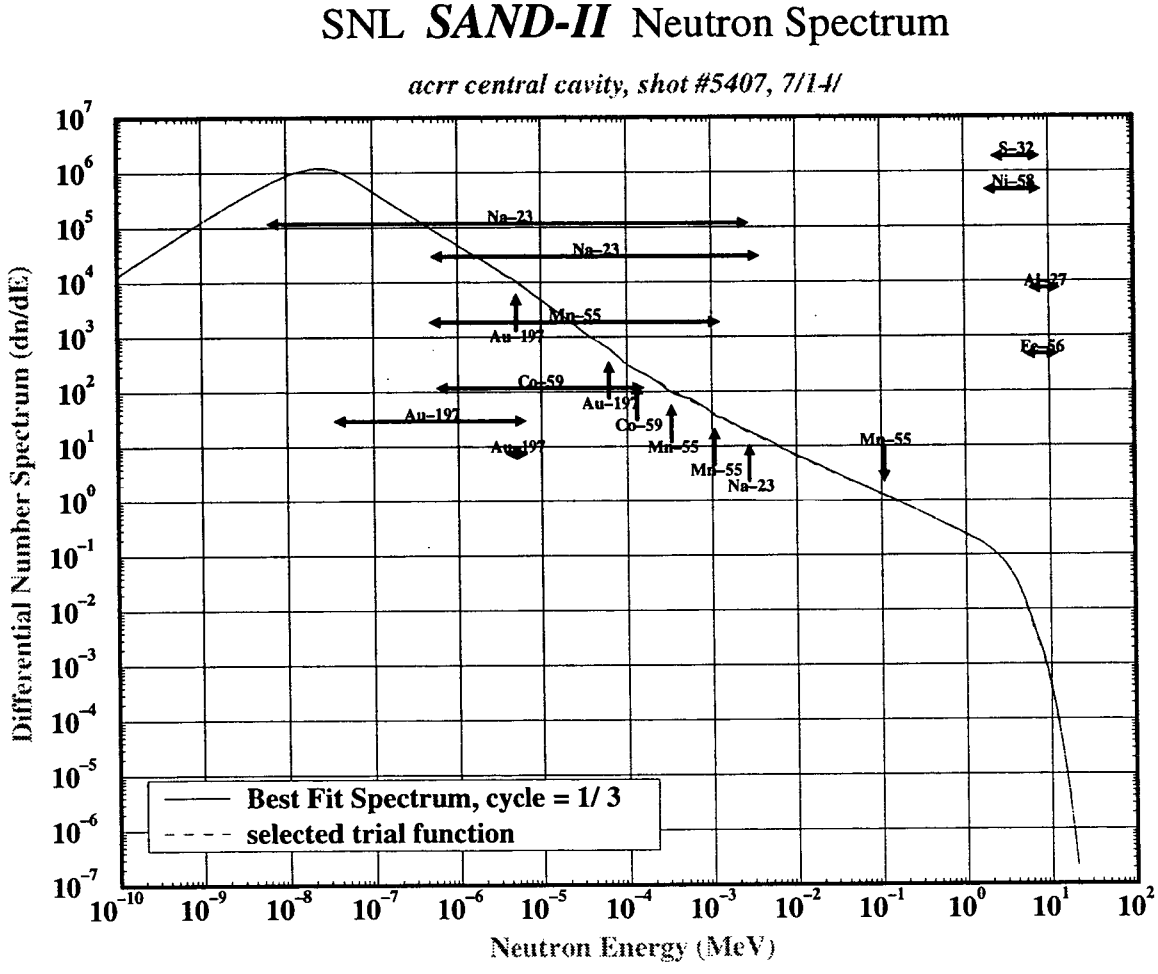

Figure B-11: ACE/gr ACF9 Spectrum Plot

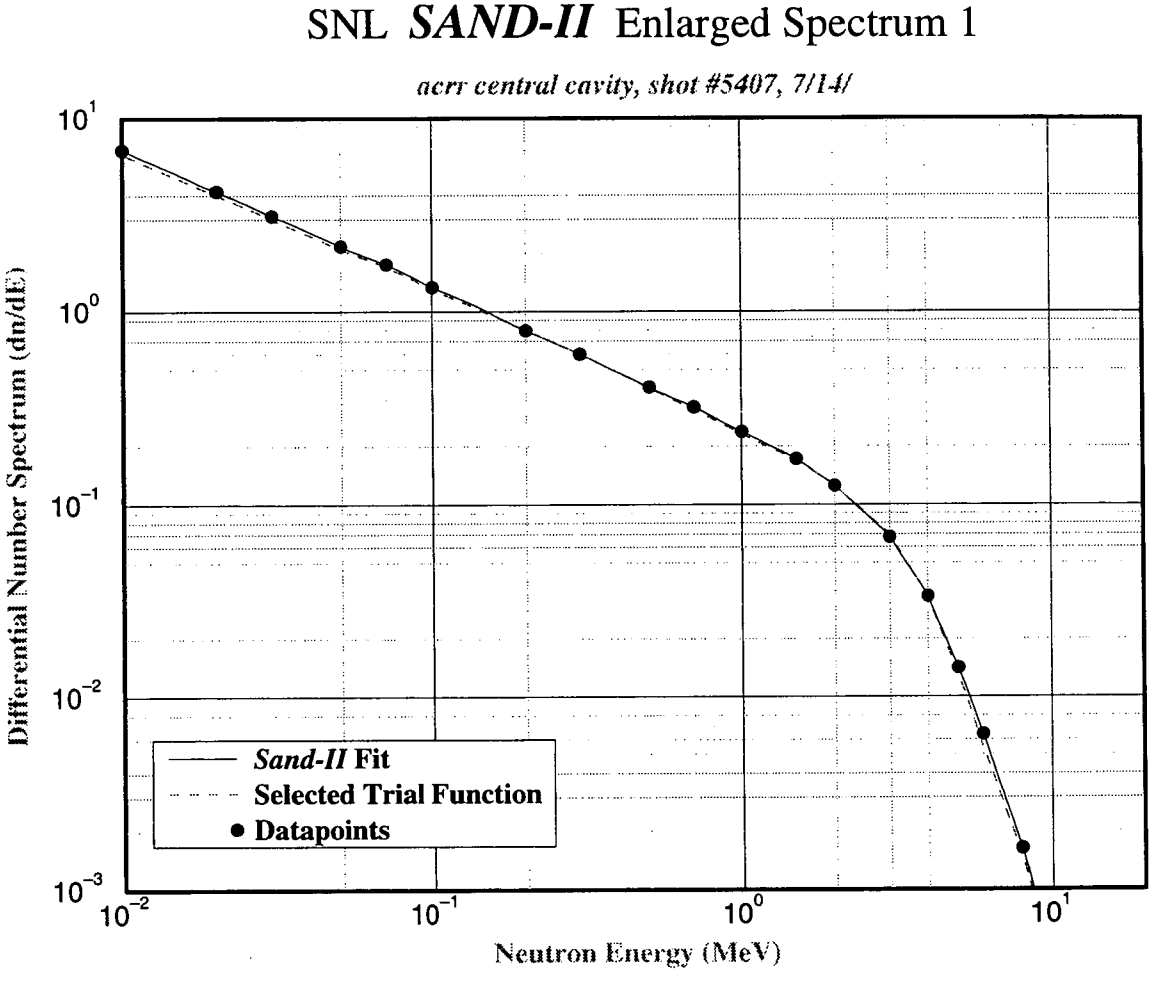

Figure B-12: ACE/gr ACF9 Enlarged Spectrum Plot

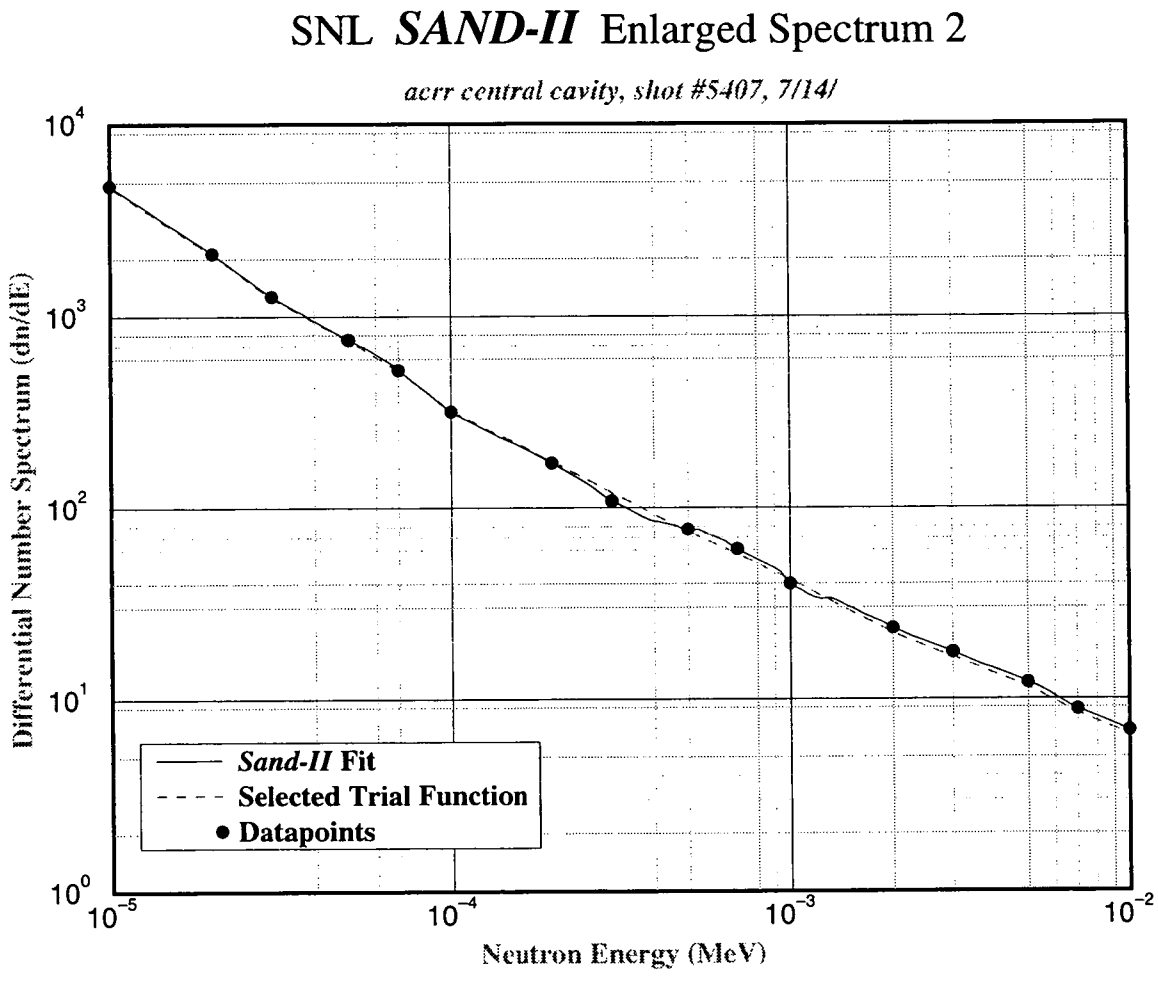

Figure B-13: ACE/gr ACF9 Enlarged Spectrum Plot

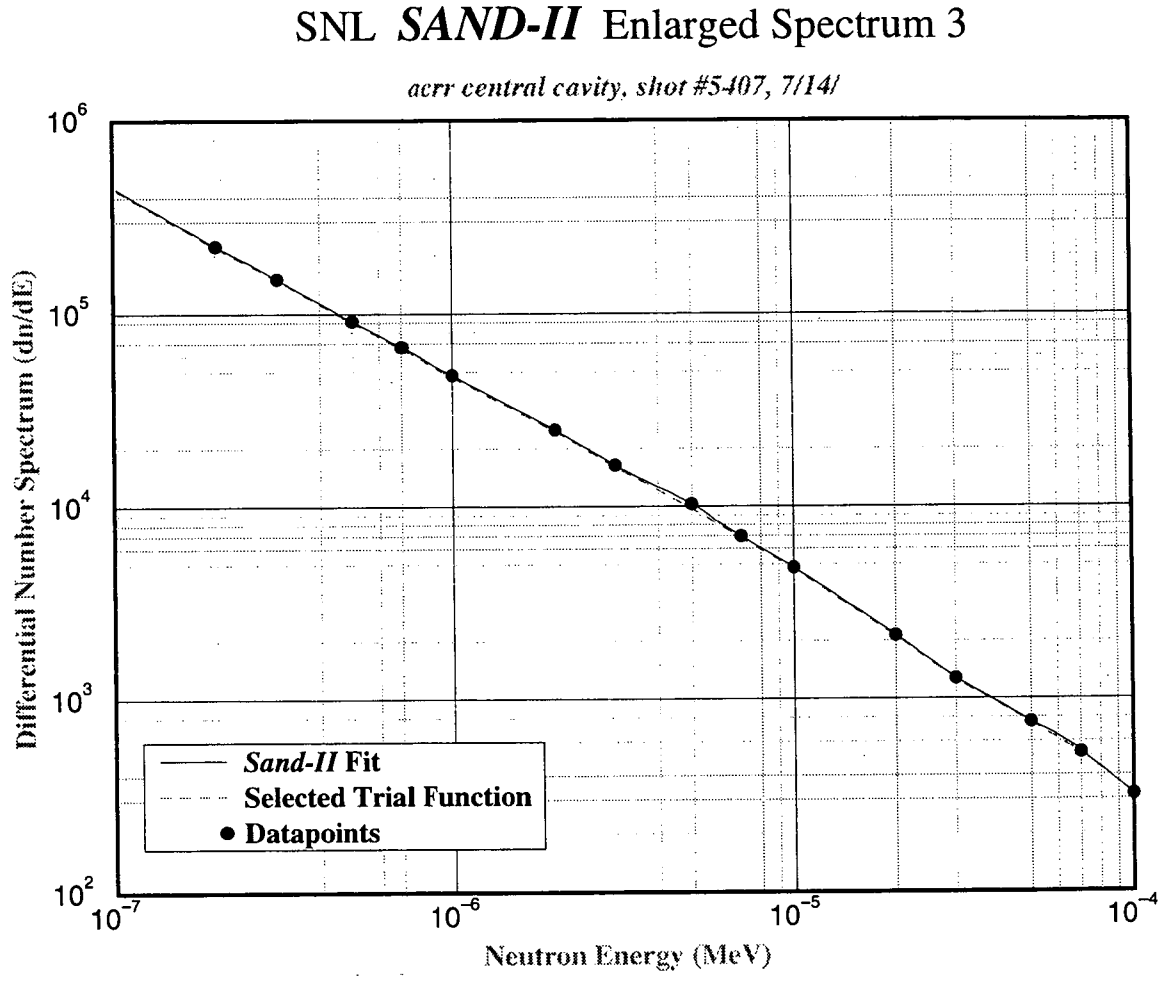

Figure B-14: ACE/gr ACF9 Enlarged Spectrum Plot

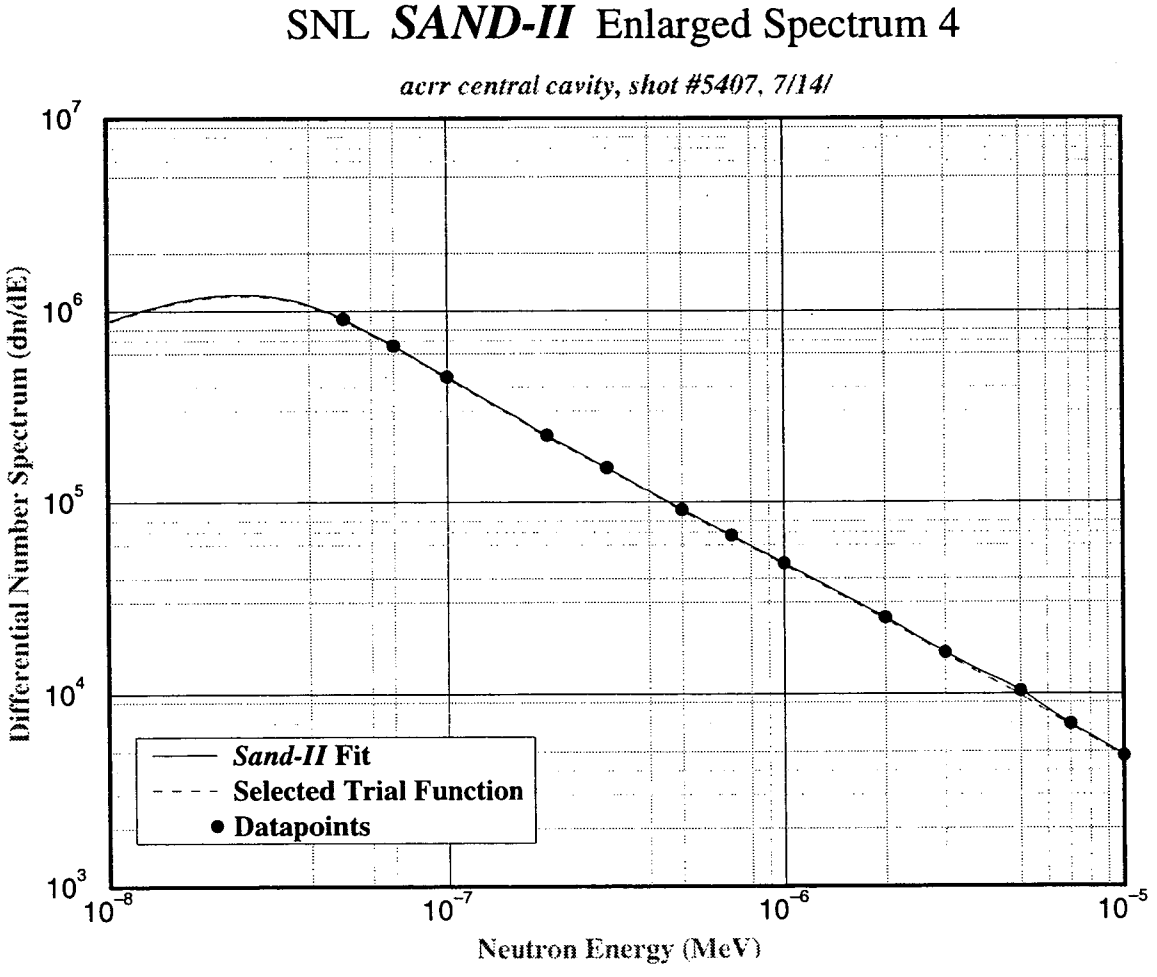

Figure B-15: ACE/gr ACF9 Enlarged Spectrum Plot

SNL-SAND-II Sample Plot 4:

Environment:	**ACRR New Pb-B_4C Bucket**
File Name:	**TPB13**
Shot Date:	**6/6/90**
Facility Shot Number:	**4681**
Run Conditions:	**160 sec @ 50 kwatt**
Dosimetry Position:	**Dosimetry placed on a cardboard ring and aluminum honeycomb was used to vertically align it with the reactor centerline. The cardboard ring diameter was 2.5 inches.**
	This bucket is composed of 3.8 cm of lead inside 1.27 cm of natural B_4C powder. Top and bottom bucket caps have 2.5 cm of lead inside 1 cm of B_4C. When this bucket is used the experimnetal package can be up to 12.7 cm in diameter.

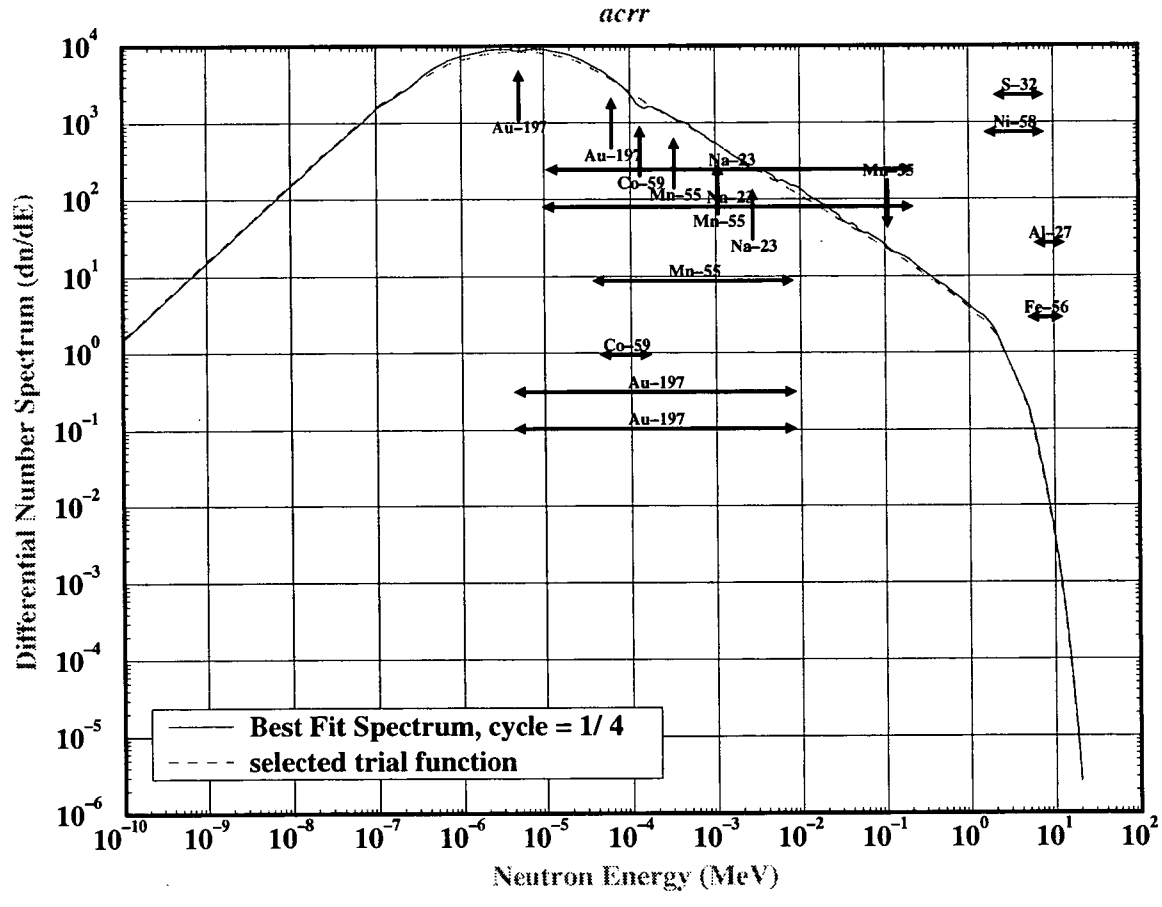

Figure B-16: ACE/gr TPB13 Spectrum Plot

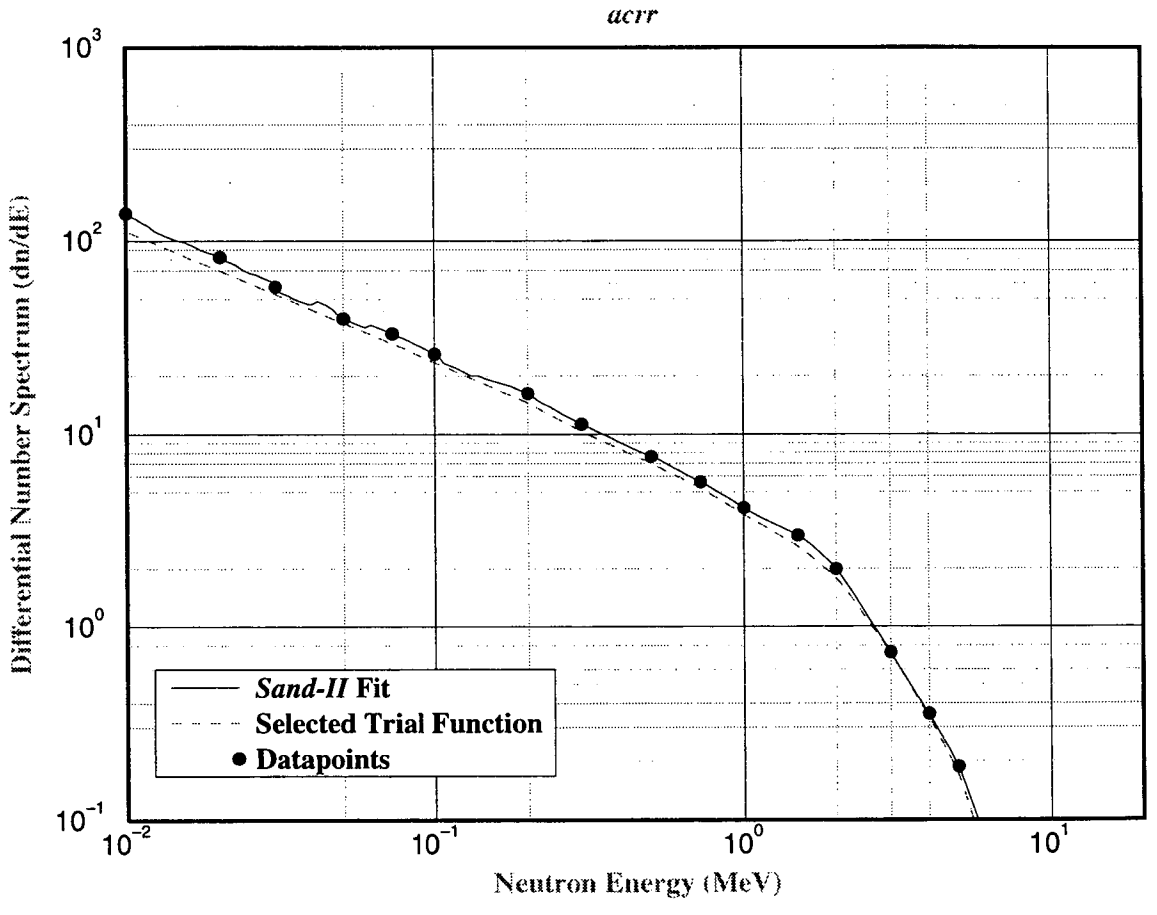

Figure B-17: ACE/gr TPB13 Enlarged Spectrum Plot

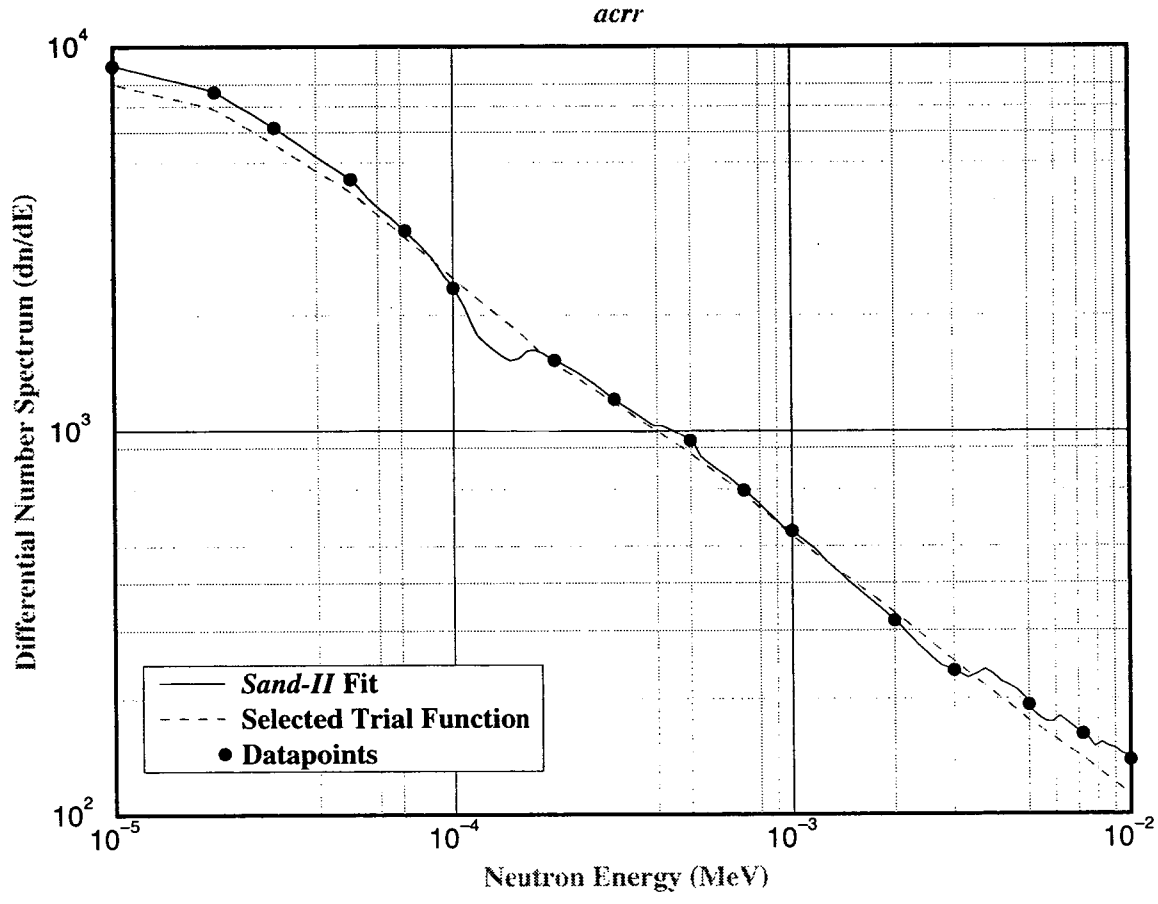

Figure B-18: ACE/gr TPB13 Enlarged Spectrum Plot

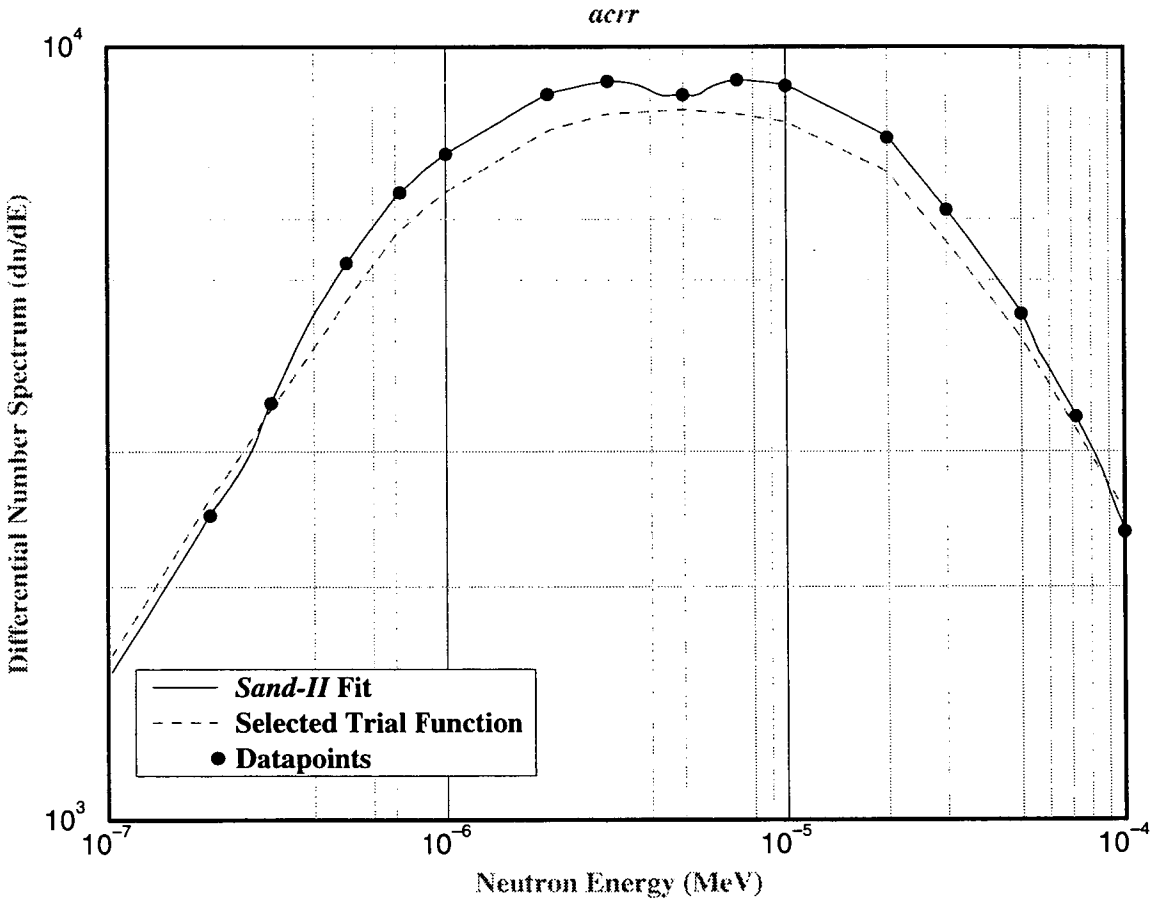

Figure B-19: ACE/gr TPB13 Enlarged Spectrum Plot

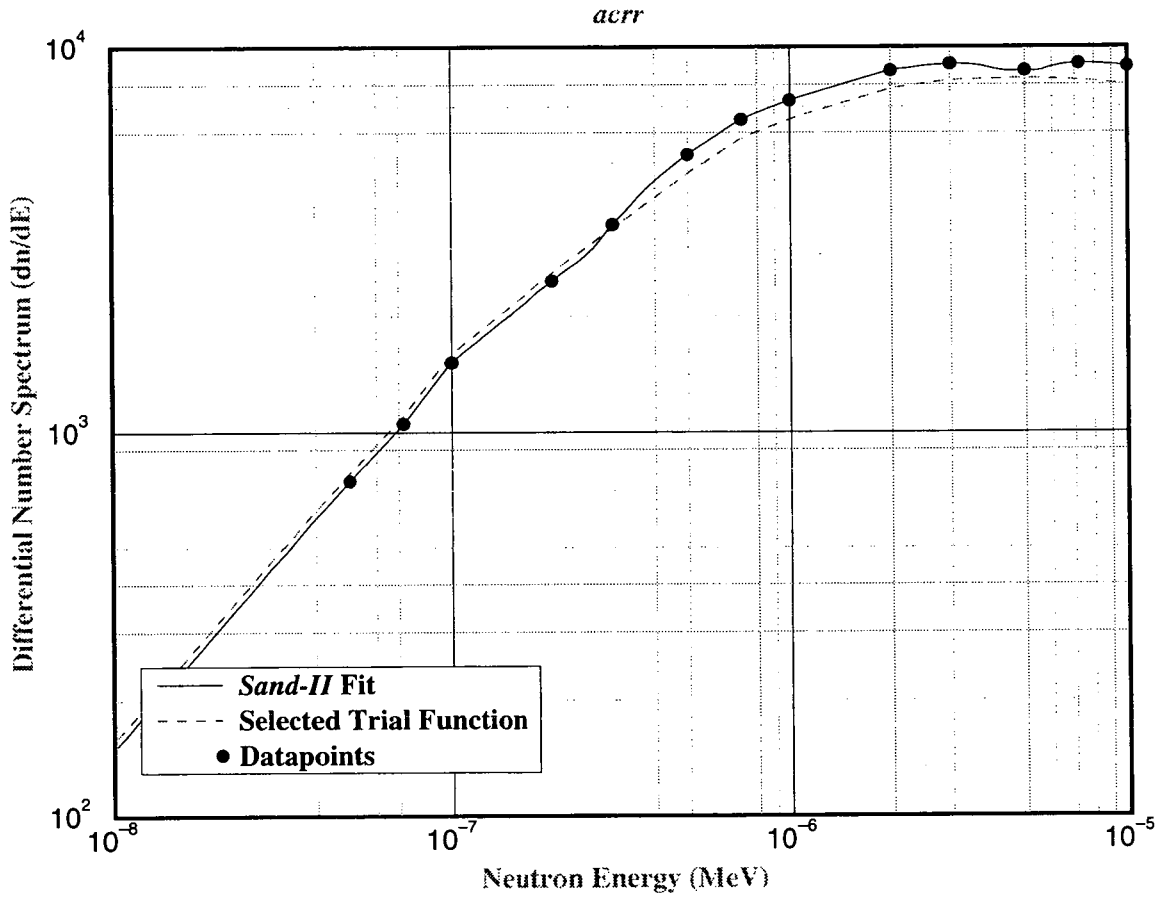

Figure B-20: ACE/gr TPB13 Enlarged Spectrum Plot

APPENDIX C

README For SNL-SAND-II

APPENDIX D

MANIFEST For SNL-SAND-II

README

SNLSAND - a spectrum unfolding computer code package.

SNLSAND V1.0 is a collection of four computer codes:

1. CSTAPE
2. SLACTS
3. SLTAPE
4. SANDII

and two supplementary program distributions:

1. ACE/gr (public domain X-based two-dimensional plotting package).
2. utils (input pre/post-processing codes).

These codes are executed independently but are dependent on data generated by each sister. The current implementation of SNLSAND requires that the directory structure be rigorously maintained. To provide this, we offer a companion CSH script for each code located in the ''input'' directory of each computer code. Within the script are commands that execute each code and control data flow from the working to storage directories. Please do not modify these scripts.

We have also provided a master CSH script that will run the first three of these codes to process the SNLRML library for use with the SANDII spectrum unfolding code. The CSH script (make_library) is located in the current working directory of this file.

INSTALLATION.

a) Making of the executable files.

For portability, SNLSAND is shipped without pre-complied object or binary files, but offers makefiles within each code's directory structure.

The makefiles are located in the following directories:

CSTAPE: ./cstape/source/makefile
SLACTS: ./slacts/source/makefile
SLTAPE: ./sltape/source/makefile
SANDII: ./sandii/source/makefile

Each of these makefiles are similar and require only one environmental variable to be set before proper compilation can occur.

Within each makefile there is an environmental variable that must be set depending on the installation directory of the SLNSAND distribution. This environmental variable, DIRSTUB, points to the highest level of the SNLSAND directory structure. i.e. if you install SNLSAND in /usr/codes/sandia, the value of DIRSTUB must be set to

```
DIRSTUB= '/usr/codes/sandia/snlsand'
```

From this working stub, each makefile references working and storage directories necessary for proper execution of the code. After this modification, each code should be compiled and installed by giving the command:

```
% make
```

b) Compiling utility programs

Two utility programs, sys_interface_1 and sys_interface_2 are provided in the /usr/codes/sandia/snlsand/utils subdirectory. These programs are invoked by the individual C-shell scripts for each SAND-II module. These utility programs allow the scripts to scan the input file and to convert comment cards into UNIX system commands. The sys_interface_1 script scans for comment cards that begin with the three-character designator " # " and executes these system-level commands BEFORE the SAND-II FORTRAN module is run. The sys_interface_2 script scans for comment cards that begin with the three-character designator " - " and executes these system-level commands AFTER the SAND-II FORTRAN module is run. These special comment cards are often used to move output and interface files to specific directory locations after a calculation.

The binary executable images for a Sun Sparc 2 are located in the /usr/codes/sandia/snlsand/utils directory. To recompile these codes on a different UNIX architecture run the setup C-shell also located in this directory. The FORTRAN code may have to be modified since the FORTRAN calling interfaces to execute operating system commands differs for different FORTRAN compilers.

If your FORTRAN compiler does not support this interface with the operatinty system, these utility commands can be eliminated from the various scripts without any seriou loss of functionality.

c) Modification of the CSH scripts.

Similar to the makefiles, each code has an independent CSH script located in the ./*/input directory which controls the execution of the programs. This CSH scripts have been given names identical to the programs that they control and have ''usage'' lines that explain their syntax. (Since this is our primary release of the code, no formal documentation is yet available for our implementation). Sorry.

Also, within each CSH script the environmental variable, ${dirstub}, again must be set to reflect the proper installation directory of SNLSAND. Here the syntax is nearly identical to that of the makefile modifications, i.e.:

```
setenv dirstub   '/usr/codes/sandia/snlsand'
```

Be careful to preserve the ''setenv'' command and do not use ''set'' since this environmental variable is used within each code to locate necessary library and auxiliary input files and information.

After these changes have been made and the computer codes properly compiled, SNLSAND is ready for use.

d) ''Making'' of the SNLRML library.

To expedite the process of creating the SNLRML library, we offer a small script at this level of the distribution that automates the process of running CSTAPE, SLACTS, and SLTAPE on the SNLRML library. This CSH script must also have it's ''dirstub'' environmental variable also updated to reflect the current installation. The process is described in the previous section. If you have gotten this far without a failure, the SNLRML library can be made by simply typing:

```
% make_library
```

All generated files will be moved to the proper directories and installation of SNLSAND with the SNLRML library will be complete.

e) Installation of the ACE/gr plotting package.

We have distributed a copy of the ACE/gr V2.09 with SNLSAND as an aid in data visualization. Since this package is under the restrictions laid out by Paul J. Turner, we cannot couple this package directly into SNLSAND but we must rely on the user to decided if implementation of ACE/gr is desired. This package is not a requirement to run SANDII, but SANDII does write interface files for ACE/gr. If you chose to use this package, we offer the following instructions:

1. Compilation of Xvgr is not necessary since xvgr-2.09 is distributed with a pre-compiled binary file for SUNOS 4.x under ./acegr/xvgr-2.09/examples/xvgr within the distributed tar-format file. We offer this file unpacked in ./acegr. To unpack the full ACE/gr distribution, execute the command:

   ```
   % zcat xvgr-2.09.tar.Z | tar -xvf -
   ```

   If you chose to use this code to view SANDII files to the screen pipe the SANDII produced .xvgr files directly into the code via the command:

   ```
   % cat {sand.output}.xvgr | xvgr -pipe
   ```

   For frequent use, you might want to move the executable to the /usr/local/bin directory and remake the hash tables through rehash(1). However, if you do move the code, note the necessary changes below in (3).

2. A plotting driver CSH script is included with the SNLSAND distribution that executes Xvgr with suppression of the X-toolkit and pipes the output to lpr. This script is located in the directory ./sandii/plot/batchplot, and is meant to be used there. Please do not erase this file if you wish to use the Xvgr plotting capability.

   Batchplot is designed to plot (as default) to a postscript printer, however you can change this default to replace direct printing to ''printing to a file'' by replacing the each occurrence of ''grbatch'' with ''grbatch -pltfile {outfilename}'' within batchplot where {outfilename} is a unique file name for each plot created by batchplot. As you can see this might prove to be cluttersome, and we recommend reserving batchplot for direct SANDII-to-hardcopy conversion.

   Further modification of run-time parameters (such as specifying MIF or HPGL output formats) can be made in a similar fashion and the user is encouraged to consult the ACE/gr manual for full details.

3. The above script runs Xvgr through a symbolic link to the

file ./acegr/xvgr-2.09/examples/xvgr, so if you move this
file, remake the symbolic link. The link is located as
./sand/plot/grbatch (this confusing naming convention is
necessary to run the toolkit suppressed option, and is
described in the ACE/gr documentation).

f) Testing SNLSAND.

We have included a set of sample files along with a small CSH script
for purposes of testing the SNLSAND installation. Included input files
are as follows:

acf9	- ACRR central cavity.
barnob6-snlrml	- Old SPR-III central cavity.
scr4	- SPR-III 17" leakage.
spr3cc	- SPR-III central cavity (spec. determination).
spr3cc-activity	- SPR-III central cavity (activity run).
spr_120	- SPR-III 120" leakage.
spr_80a3	- SPR-III 80" leakage.
tpb13	- ACRR new Pb-B bucket (normed to 3MeV fluence).
tpb13_full-response	- ACRR new Pb-B bucket (foil sensitivity analysis).
cf252-activity	- 252Cf benchmark spectrum from ENDF/B-VI (activity run).

The CSH script (testall) runs these files through SANDII and compares
the (*.prt) files with samples output cases found in ./sandii/output/samples.
The output of the each comparison is stored in the file (diffout) found
at the end of the test run in the ./sandii/input directory.

PROBLEMS WITH SNLSAND.

If during the process of installation or execution you discover a
programming error, installation bug, or script error please report this
immediately to either:

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Also, your comments or recommendations for further enhancements are
gladfully accepted. Thank you.

(EOF:JWV:PJG:14 April 1994)

APPENDIX E

Code Abstract For RSIC

ABSTRACT
for
RSIC DATA LIBRARY SUBMISSION

1. NAME AND TITLE OF DATA LIBRARY

SNL-SAND-II

2. NAME AND TITLE OF DATA RETRIEVAL PROGRAM

As with the original SAND-II program, this code system consists of four modules, CSTAPE, SLACTS, SLATPE, and SANDII. The first three modules pre-process the dosimetry cross sections and the trial function spectrum library. The last module, SANDII, actually performs the iterative spectrum characterization.

3. CONTRIBUTOR

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4. HISTORICAL BACKGROUND AND INFORMATION

This is the latest Sandia National Laboratories' (SNL) version of the SAND-II (RSIC code package CCC-112) code [1]. This version of SAND-II has been ported to a SUN Sparc UNIX platform and has enhanced input, output, and plotting interfaces. The latest dosimetry cross sections, the SNLRML (available from RSIC and distributed with this code package), is also interfaced with this code.

5. APPLICATION OF THE DATA

SNL-SAND-II will perform an iterative "unfolding" of a neutron spectrum. SNL has found that this SNL-SAND-II code is the most appropriate means of determining a spectrum for a neutron environment at a research reactor. Other spectrum determination codes, such as LSLM2, may be better suited to characterize specific spectrum-averaged integral parameters and their uncertainty.

6. SOURCE AND SCOPE OF DATA

See the discussion in sections 4 and 5.

7. DISCUSSION OF THE DATA RETRIEVAL PROGRAM

An installation script is included. After the "tar" file has been expanded with the "tar -xvf /dev/rst0" command, a README file gives complete program installation and testing instructions.

8. DATA FORMAT AND COMPUTER

The code is delivered as a "tar" format file on 1/4" tape. The code is designed to run on a SUN Sparc 2 system under SUN OS 4.1.2 and OPENWINDOWS. The code should be easily ported to any UNIX system.

9. TYPICAL RUNNING TIME

A typical run time for the SANDII module is 2 minutes on a SUN Sparc 2. When a CSTAPE/SLACTS/SLTAPE run is made to create a binary library, the typical run time is 5 minutes.

10. REFERENCE

[1] W. N. McElroy, S. Berg, T. Crockett, and R. Hawkins, "**A Computer-Automated Iterative Method for Neutron Flux Spectral Determination by Foil Activation,**" AFWL-TR-67-41, Vol. 1, Air Force Weapons Laboratory, Kirkland, New Mexico, July 1967.

[2] P. J. Griffin, J. G. Kelly, T. F. Luera, J. VanDenburg, "**SNL RML Recommended Dosimetry Cross Section Compendium,**" SAND92-0094, Sandia National Laboratories, Albuquerque, NM, November1993.

[3] P.J. Griffin, J.G. Kelly, D.W. Vehar, "**Updated Neutron Spectrum Characterization of SNL Baseline Reactor Environments, Volume 1**" SAND93-2554, Sandia National Laboratories, April1994.

[4] J. G. Kelly, "**Neutron Spectrum Adjustment with SANDII Using Arbitrary Trial Functions,**" Reactor Dosimetry: Methods, Applications, and Standardization, ASTM STP 1001, Harry Farrar IV and E. P. Lippincott, Eds., American Society for Testing and Materials, Philadelphia, 1989, pp. 460-468.

[5] J. G. Kelly, D. W. Vehar, "**Measurement of Neutron Spectra in Varied Environments by the Foil-Activation Method With Arbitrary Trials,**" SAND87-1330, Sandia National Laboratory, December 1987.

[6] P. J. Turner, "**ACE/gr User's Manual: Graphics for exploratory data analysis,**" Center for Coastal and Land-Margin Research, Oregon Graduate Institute of Science and Technology, Software Documentation Series SDS3, 91-3, 1991.

[7] P. J. Griffin, J. G. Kelly, J. G., "**Status of Neutron Dosimetry Cross Sections,**" Reactor Dosimetry ASTM STP 1228. Harry Farrar IV, E. Parvin Lippincott, John G. Williams, and David W. Vehar, Eds., American Society for Testing and Materials, Philadelphia, 1994.

[8] P. J. Griffin, J. G. Kelly, T. F. Luera, "**Effect of New Cross Section Evaluations on Spectrum Determinations**," IEEE Transactions on Nuclear Science, Vol. 39, No. 6, pp. 2078-2085, Dec. 1992.

11. CONTENTS OF LIBRARY

The library is delivered in the format of a "tar" file. The library contents are listed in the code MANIFEST. A copy of the MANIFEST appears as Appendix D in report SAND93-3957. References 1 and 2 are available from other code packages distributed by RSIC. Reference 6 is contained as a Postscript file in the delivered contents. It appears as an element of snlsand/acegr/xvgr-2.09.tar. References 7 and 8 are attached.

12. DATA OF ABSTRACT

February 15, 1994

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